

Fishery Data Series No. 91-47

Stock Assessment of Arctic Grayling in the Tangle Lakes System, 1990

by

William P. Ridder

September 1991

Alaska Department of Fish and Game

Division of Sport Fish



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William P. Ridder

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

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TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES.....	iii
LIST OF FIGURES.....	v
LIST OF APPENDICES.....	vi
ABSTRACT.....	1
INTRODUCTION.....	2
STUDY SITE.....	5
METHODS.....	6
Data Collection.....	6
Sex and Maturity.....	7
Estimation of Age and Size Composition.....	8
Estimation of Abundance.....	12
Estimation of Mixing Rates.....	14
RESULTS AND DISCUSSION.....	16
Spring Sampling Summary.....	16
Lower System.....	17
Upper System.....	17
Rock Creek.....	20
Summer Sampling Summary.....	20
Fall Sampling Summary.....	22
Sex and Maturity.....	22
Age Composition.....	26
Size Composition.....	33
Abundance.....	33
Mixing Rates.....	40
Mixing of Fish Tagged in Spring.....	40
Mixing of Fish Tagged in Summer.....	45

TABLE OF CONTENTS (Continued)

	<u>Page</u>
Mixing of Fish Tagged in Fall.....	45
Summary.....	45
ACKNOWLEDGEMENTS.....	51
LITERATURE CITED.....	51
APPENDIX A - Harvest and Effort Statistics.....	57
APPENDIX B - Detection of Bias.....	59
APPENDIX C - Catch Summaries	66
APPENDIX D - Unadjusted Age and Size Compositions.....	77

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1. Summary of Arctic grayling caught, marked, and recaptured in the Tangle Lakes system, 23 May through 27 August 1990.....	9
2. Sex ratios (male:female) of mature Arctic grayling by location and gear type in the Tangle Lakes system, 22 May through 7 June 1990.....	25
3. Percent mature Arctic grayling in 10 mm FL groups sampled from seven locations of the Tangle Lakes system, 22 May through 6 June 1990.....	29
4. Percent mature Arctic grayling in age classes sampled from seven locations in the Tangle Lakes system, 22 May through 6 June 1990.....	30
5. Age composition estimates by gear type and location for mature Arctic grayling sampled from six locations in the Tangle Lakes system, 22 May through 7 June 1990.	31
6. Age composition estimates and standard errors for mature male and female Arctic grayling sampled from five locations in the Tangle Lakes system, 22 May through 6 June 1990.....	34
7. Mean fork length at age for mature male and female Arctic grayling sampled from five locations in the Tangle Lakes system, 22 May through 6 June 1990.....	35
8. Summary of Relative Stock Density (RSD) indices for mature Arctic grayling in the Tangle lakes system by area, gear type, and sex, 22 May through 7 June 1990...	36
9. Sample sizes and estimated abundance of mature Arctic grayling in the spawning aggregation in Tundra Pond of 18 Mile Creek, Tangle Lakes system, May 1990.....	38
10. Sample sizes and estimated abundance of mature Arctic grayling in the spawning aggregation in thoroughfares in Long Tangle Lake, June 1990.....	39
11. Summary of recaptures of Arctic grayling tagged in the Tangle Lakes system by season and origin, 1986 through 1990.....	41

LIST OF TABLES (Continued)

<u>Table</u>	<u>Page</u>
12. Relative mixing rates of all Arctic grayling tagged in the spring and recaptured in the spring at least one year later in the Tangle Lakes system from 1988 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	42
13. Relative mixing rates of all Arctic grayling tagged in the spring and recaptured in the summer in the Tangle Lakes system from 1988 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	43
14. Relative mixing rates of all Arctic grayling tagged in the spring and recaptured in the fall in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	44
15. Relative mixing rates of all Arctic grayling tagged in the summer and recaptured in the spring in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	46
16. Relative mixing rates of all Arctic grayling tagged in the summer and recaptured in the summer at least one year later in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	47
17. Relative mixing rates of all Arctic grayling tagged in the summer and recaptured in the fall in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	48
18. Relative mixing rates of all Arctic grayling tagged in the fall and recaptured in the spring in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	49
19. Relative mixing rates of all Arctic grayling tagged in the fall and recaptured in the summer in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	50

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. Map of the Tangle Lakes and River system.....	3
2. Estimated recreational harvest of Arctic grayling and total angling effort on the Tangle Lakes system, 1978 through 1989.....	4
3. Capture locations of Arctic grayling in the lower Tangle Lakes system, spring 1990.....	18
4. Capture locations of Arctic grayling in the upper Tangle Lakes system, spring 1990.....	19
5. Capture locations of Arctic grayling in upper Rock Creek, spring 1990.....	21
6. Comparison of the length frequencies of Arctic grayling in 10 mm FL groups sampled from four summer feeding locations in the Tangle Lakes system, July 1990. Sample sizes are shown above the bars.....	23
7. Comparison of the length frequencies of Arctic grayling in 10 mm FL groups sampled from three summer feeding locations in the Tangle Lakes system, August 1990. Sample sizes are shown above the bars.....	24
8. Cumulative distribution function of lengths of mature male Arctic grayling versus lengths of mature female Arctic grayling in the Tangle Lakes system (Rock Creek excluded), 22 May through 6 June 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.....	27
9. Cumulative distribution function of lengths of mature Arctic grayling captured in 1989 versus those captured in 1990 in the Tangle Lakes system (Rock Creek excluded). Statistics are from the Kolmogorov-Smirnov two-sample test.....	28

LIST OF APPENDICES

<u>Appendix</u>	<u>Page</u>
A1. Estimated recreational harvest of Arctic grayling and total angling effort on the Tangle Lakes system, 1978 through 1989.....	58
B1. Methodologies for alleviating bias due to gear selectivity by means of statistical inference.....	60
B2. Cumulative distribution functions of lengths of mature Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for the Tundra Pond of 18 Mile Creek, 22 through 28 May 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.....	61
B3. Cumulative distribution functions of lengths of mature Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for the thoroughfare in mid-Long Tangle Lake, 4 through 6 June 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.....	62
B4. Three combinations of cumulative distribution functions of lengths of mature Arctic grayling captured during three events at the head of Mud Lake, 31 May through 3 June 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.....	63
B5. Cumulative distribution functions of lengths of mature Arctic grayling captured during two events at the outlet to Lower Tangle Lake, 5 and 6 June 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.....	64
B6. Cumulative distribution functions of lengths of mature Arctic grayling captured by hook and line versus those captured by electrofishing (A) and between hook and line sample events (B) at the head of Long Tangle Lake, 2 through 6 June 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.....	65
C1. Unadjusted age composition estimates by gear type and location for all Arctic grayling sampled from six locations in the Tangle Lakes system, 22 May through 7 June 1990.....	67

LIST OF APPENDICES (Continued)

<u>Appendix</u>	<u>Page</u>
C2. Unadjusted age composition estimates by area for all Arctic grayling sampled from four locations in the Tangle Lakes system, July and August 1990.....	69
C3. Unadjusted mean fork length at age for Arctic grayling sampled from six locations in the Tangle Lakes system, 22 May through 7 June 1990.....	70
C4. Unadjusted mean fork length at age for Arctic grayling sampled from four locations in the Tangle Lakes system, July and August 1990.....	71
C5. Unadjusted mean fork length at age for mature male Arctic grayling sampled from six locations in the Tangle Lakes system, 22 May through 7 June 1990.....	72
C6. Unadjusted mean fork length at age for mature female Arctic grayling sampled from six locations in the Tangle Lakes system, 22 May through 7 June 1990.....	73
C7. Summary of unadjusted Relative Stock Density (RSD) indices for Arctic grayling in the Tangle lakes system by area, date, and gear type during 1990.....	74
D1. Summary of all Arctic grayling sampled in the Tangle Lakes system from 1986 through 1990. Samples are partitioned by year, location, maturity, and season....	78
D2. Summary of all Arctic grayling marked and released in the Tangle Lakes system from 1986 through 1990. Samples are partitioned by year, location, maturity, and season.....	80
D3. Summary of all recaptures of Arctic grayling by maturity, season, and location tagged during spring in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	82
D4. Summary of all recaptures of Arctic grayling by maturity, season, and location tagged during summer in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	86

LIST OF APPENDICES (Continued)

<u>Appendix</u>	<u>Page</u>
D5. Summary of all recaptures of Arctic grayling by maturity, season, and location tagged during fall in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.....	89

ABSTRACT

Results are presented for the third year of a study to assess the population parameters and mixing rates of Arctic grayling *Thymallus arcticus* among their major spawning, summer feeding, and overwintering locations in the Tangle Lakes system above the Delta River falls. Between 22 May and 24 August 1990 a total of 3,084 Arctic grayling was sampled during three distinct time periods. A total of 196 recaptures of previously tagged Arctic grayling was obtained. Angler-volunteered returns totaled an additional 131 recaptures. Analysis of recapture data implied the existence of significant movement throughout the Tangle Lakes system by season. Insufficient recaptures across years and lack of 1988 spawning area samples precluded reliable estimation of mixing rates. The estimated abundance of mature Arctic grayling in the Tundra Pond of 18 Mile Creek was 1,251, and in spawning areas of Long Tangle Lake was 764. Mature fish were first detected at lengths of 250 to 259 millimeters and age 4. All fish were mature above a length of 370 millimeters and age 9. Ages ranged from ages 4 to 9, with the predominant age being 6 years. The majority of fish were in the quality category of the Relative Stock Density index. Adult males were significantly larger and older than adult females.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, Tangle Lakes, Tangle River, Delta River, age composition, size composition, Relative Stock Density, maturity, mixing rates

INTRODUCTION

The Tangle Lakes and River system, hereafter referred to as the Tangle System (Figure 1), supports a large population of Arctic grayling *Thymallus arcticus* and populations of lake trout *Salvelinus namaycush*, burbot *Lota lota*, round whitefish *Prosopium cylindraceum*, and longnose suckers *Catostomus catostomus*. The Tangle System has supported popular fisheries for Arctic grayling, lake trout, and burbot since the opening of the Denali Highway on 4 July 1953 (Wojcik 1953a). Prior to this time, the Tangle System was inaccessible by road and received little fishing pressure (Wojcik 1953a, 1953b, 1953c, 1953d, 1953e, 1953f, 1953g). Since 1953, the heaviest angling pressure has occurred on Upper and Round Tangle lakes and the interconnecting Tangle River.

The recreational fishery in the Tangle System targets Arctic grayling, lake trout, and burbot with Arctic grayling comprising over 80% of the system's total harvest. From 1978 to 1989, an average of 5,668 angler-days were expended annually for all species. Arctic grayling harvests ranged from 2,467 to 9,590 fish, with an annual average of 5,962 fish (Mills 1979-1990; Figure 2; Appendix A1). This average annual Arctic grayling harvest is the fifth largest in Alaska (Mills 1979-1990). Lake trout and burbot harvests have averaged 988 and 109 fish per year, respectively since 1978 (Mills 1979-1990). Depressed population levels in the latter two fisheries necessitated their closure by emergency order in 1987. These closures appear to have indirectly affected the harvest of Arctic grayling in the Tangle System. In 1987, angling pressure dropped to its lowest recorded level and harvest was reduced to 2,467 Arctic grayling (Figure 2). With new regulations in 1988 which allowed a minimum harvest of lake trout and burbot, angling pressure for all species and Arctic grayling harvest have moderately increased (Mills 1990).

Since 1953, numerous studies have been conducted to assess the population structure of Arctic grayling in the Tangle System (Wojcik 1953a, 1953b, 1953c, 1953d, 1953e, 1953f, 1953g; Warner 1955a, 1955b, 1956, 1957, 1958, 1959; Heckart 1965; Roguski 1967; Roguski and Winslow 1969; Roguski and Tack 1970; Schallock 1966; Peckham 1974, 1977; Holmes et al. 1986; Clark and Ridder 1987, 1988; and Baker 1989). The majority of these studies have presented limited data, quantitative or qualitative, on harvest rates, movements, location-specific population estimates, and age and size compositions. As presented, these data are not comparable from year to year. However, some basic conclusions about Arctic grayling population(s) in the Tangle System can be made from these and other studies.

As with riverine populations in interior Alaska (Tack 1980), Arctic grayling are highly mobile and migrate throughout the Tangle System between spawning, summer feeding, and overwintering locations (Wojcik 1953d; Warner 1955a; Schallock 1966). In spring, Arctic grayling concentrate at or near spawning locations. After spawning, fish move to summer feeding locations in the rivers, creeks, and thoroughfares between the lakes. In the fall before ice-up, the fish move back to main lakes where they overwinter. Based on the strong homing to feeding locations and, most likely, spawning locations found in studies of riverine populations (Tack 1980; Ridder *in press*), separate populations, or stocks, of Arctic grayling may exist in the Tangle System. From the analysis of past movement studies, the majority of Arctic grayling in

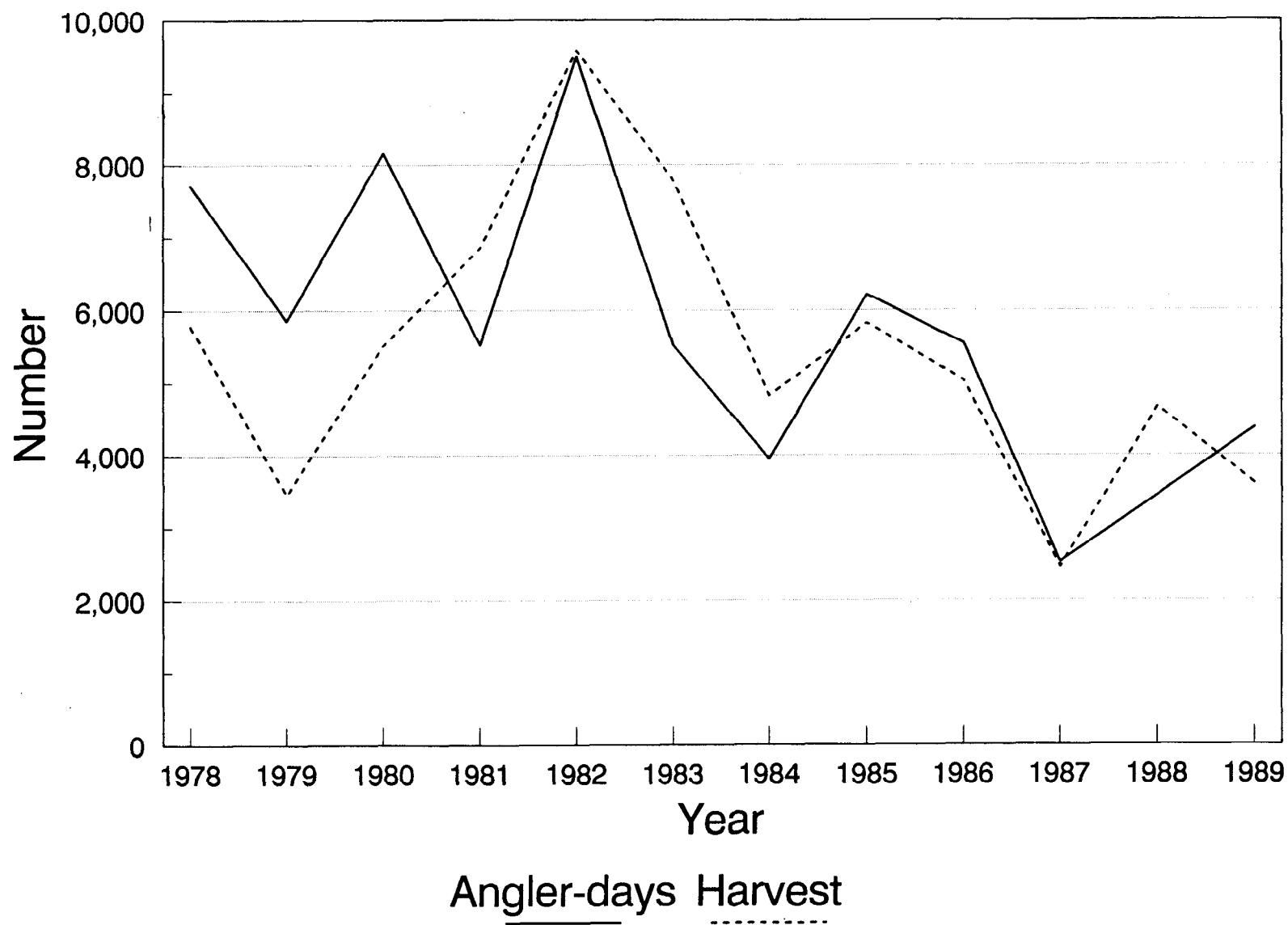
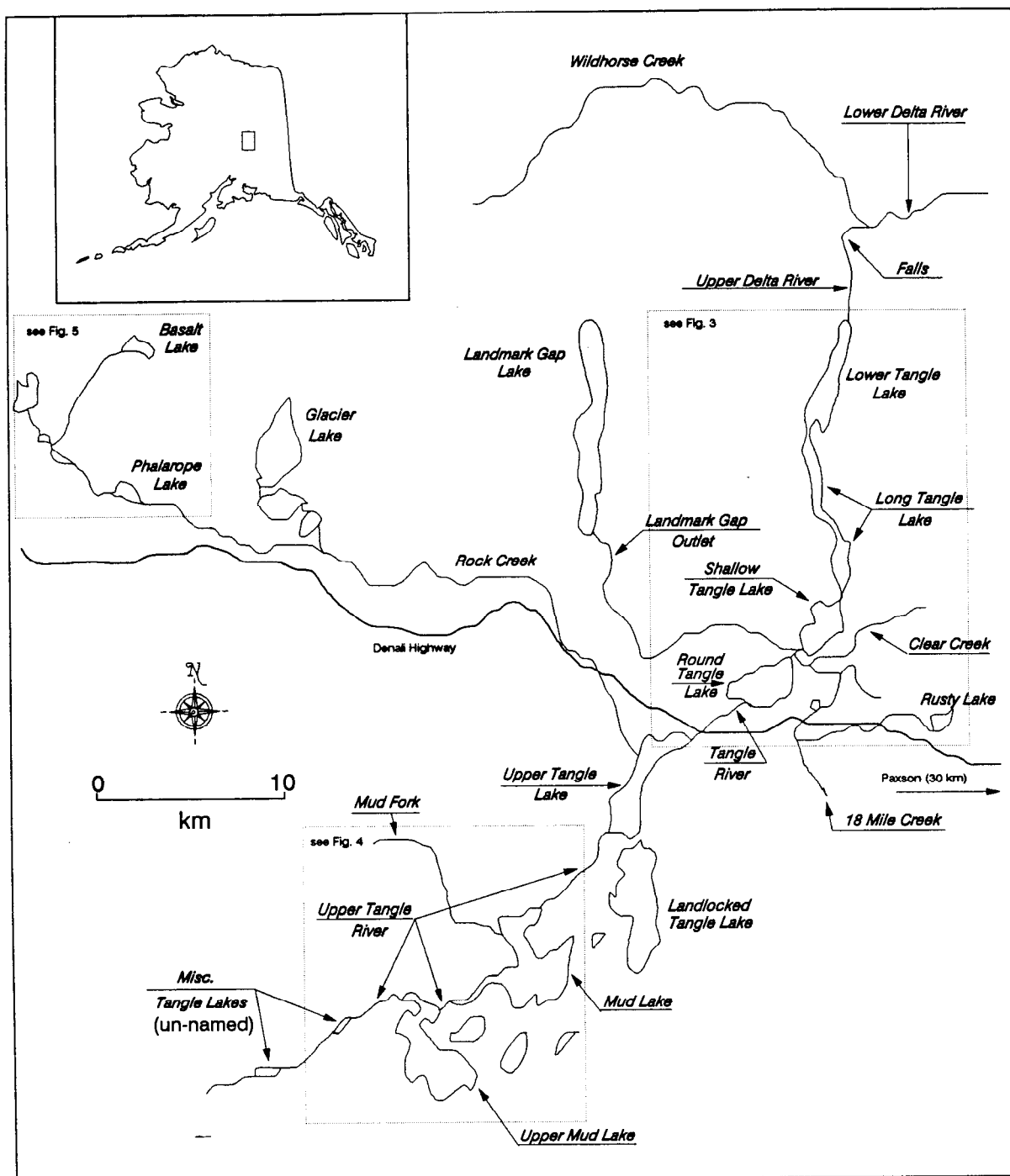


Figure 1. Estimated recreational harvest of Arctic grayling and total angling effort on the Tangle Lakes system, 1978 through 1989.



the Tangle System also appear to use the same feeding locations yearly. The extent of mixing of spawning stocks in summer feeding locations is unknown. Differential harvest rates among feeding locations within the Tangle System could result in overexploitation of one, many or all spawning stocks.

A research project was initiated in 1988 to assess the stock status of Arctic grayling in the Tangle System. This report summarizes results from year three (1990) of the project. The specific objectives of this year's research project were to estimate:

1. mixing rates of Arctic grayling among their major spawning and summer-rearing areas in the Tangle System;
2. age composition of spawning concentrations of Arctic grayling in the Tangle System; and,
3. size composition of spawning concentrations of Arctic grayling in the Tangle System.

STUDY SITE

The Tangle System is an interconnected lake-stream system located approximately 37 km west of Paxson on the Denali Highway (Figure 1). The highway bisects the system at the Tangle River between Round and Upper Tangle lakes. There are two Bureau of Land Management (BLM) campgrounds located next to the highway at the two lakes. The Tangle System is approximately 900 m in elevation and within its drainage are 12 major lakes and over 100 km of rivers and streams. The lakes range in size from 12 ha (Rusty Lake) to 304 ha (Landmark Gap Lake) and cumulatively cover a surface area of over 1,500 ha. The open-water season in the Tangle System is about four and a half months (June to the middle of October). However, some open water persists all year at the inlets and outlets of rivers and streams and the thoroughfares between lakes.

The Tangle System is composed of seven main lakes (proceeding upstream; Lower Tangle, Long Tangle, Shallow Tangle, Round Tangle, and Upper Tangle, Mud, and Upper Mud lakes) that are interconnected by the Tangle River¹. The maximum depth of the lakes is 35 m in Round Tangle Lake. The Delta River drains Lower Tangle Lake into the Tanana River. Approximately 3 km downstream of the Delta River headwaters are a series of falls that prevent fish from moving upstream (Peckham 1974)². At the headwaters of the Tangle System above Upper Tangle and Mud lakes, there are a series of unnamed lakes that form the headwaters of

¹ This report refers to the Tangle River as that section connecting Upper and Round Tangle lakes. The river above Upper Tangle Lake is the Upper Tangle River. The shorter interconnecting streams between the major lakes are referred to as thoroughfares and are named by the lake at their head. Long Tangle Lake is actually a series of three lakes connected by two thoroughfares (see Figure 3).

² In this report, the river above the falls is called the Upper Delta River and below the falls, the Lower Delta River.

the Tangle River (Figure 1). There are also two large tributaries that drain into two of the main lakes. Rock Creek (30 km long) flows into Upper Tangle Lake. It flows through a number of small, shallow lakes near its headwaters and includes the outflow of Glacier Lake (172 ha) near its middle reaches. Landmark Gap Lake flows via 6 km long Landmark Gap Creek into the thoroughfare between Round and Shallow Tangle lakes.

A portion of the Tangle System comprises a popular float trip that extends 41 km from Round Tangle Lake downstream to the Richardson Highway at Phelan Creek. It includes 28 km of the Delta River (Figure 1). The Alaska National Lands Conservation Act of 2 December 1980 established the Tangle Lakes system as The Delta National Wild and Scenic River corridor, a component of the National Wild and Scenic River System. The "scenic" portion lies above the Delta River. The "wild" portion extends from the Delta River headwaters 18.4 km to Eureka Creek, a glacial fed tributary.

METHODS

Data Collection

Sampling events were temporally stratified to target spawning and feeding aggregations of mature Arctic grayling. To minimize the capture of fish during the assumed seasonal inter-area movement, sampling effort occurred during 22 May through 7 June, and 4 through 20 July. Spring sampling was concentrated in spawning areas at three locations discovered in 1989: the Tundra Pond in 18 Mile Creek; the head of Long Tangle Lake; and, the head of Mud Lake. Sampling of summer feeding aggregations in 1990 targeted four of the five areas sampled in 1989: Rock and Landmark Gap creeks; the thoroughfare in mid-Long Tangle Lake; and, the Upper Delta River. The fifth area, Glacier Lake was sampled in late August in 1990 during a lake trout study where incidental catches of Arctic grayling were sampled for lengths and tagged. Late August (fall) sampling was also conducted in Landmark Gap and Rock creeks to increase samples of adult fish and tag recaptures.

Arctic grayling were captured with an electrofishing boat, an electrofishing back-pack unit, seines, gill nets, and hook and line. The electrofishing boat was equipped with a pulsed DC variable voltage pulsator (Coffelt Model VVP-15) powered by a 3.5 KW gas generator. Anodes were four 10 mm diameter steel cables 1.5 m long arranged perpendicular to the long axis of the boat and 2.1 m forward of the bow. The unpainted bottom of the boat was the cathode. Voltages ranged from 230 to 300 VDC and current ranged from 1 to 3 amperes. Duty cycle and pulse width were held constant at 40% and 80 Hz, respectively. Conductivity was not recorded in 1990 but was 230 μ S (standardized to 25°C) on 9 June 1989 at Upper Tangle Lake (Ridder 1990). The back-pack unit (Coffelt Model Mark 10) utilized DC voltage (350 volts and 1 ampere) and factory set duty cycle and pulse width. A 6.3 mm bag seine (23 m x 1.8 m) was used in Upper Tangle River and the outlet to Upper Mud Lake. Gill nets were constructed from 25 mm mesh (37 m x 1.8 m) and were used at Glacier Lake. Optimal gear type was determined by sampling conditions and gear efficiency. Spring sampling utilized all types while summer feeding areas were sampled

with hook and line gear exclusively with artificial flies as the terminal gear.

All captured Arctic grayling were measured to the nearest 1 mm in fork length (FL). Arctic grayling greater than 199 mm FL were tagged with an individually-numbered Floy internal anchor tag and given a partial clip of the right ventral fin for determination of tag loss. Sex was recorded for only those adult fish sampled during the spring sampling event. Date, location, fork length, sex, finclip, tag number, and gear type were recorded for individual fish on either coin envelopes or mark-sense (optical scanning) forms. Data recorded on coin envelopes were later transcribed onto mark-sense forms. Location codes used were the same as those first used by Baker (1989) in 1988.

For aging of sampled Arctic grayling, a minimum of two scales from all initial captures was removed from an area four to six scale rows above the lateral line just posterior to the insertion of the dorsal fin. Scales were placed in a coin envelope marked with either the above data, or the litho-code and fish number of the mark-sense form. Scales were processed by cleaning in a hot solution of common dish detergent. Scales were inspected for regeneration, and then the two best scales from each fish were mounted on gummed cards. The cards were used to make impressions of the scales on 20 mil acetate film using a Carver press at 7,000 kg/cm² (137,895 kPa) heated to 97°C. Ages were determined by a single reading of each acetate with the aid of a microfiche reader (40X magnification).

Sex and Maturity

Since spring sampling occurred during or immediately after the spawning period of Arctic grayling (Tack 1980), sex and maturity were readily determined by either sexual dimorphism or the release of gametes during handling. Dimorphism is evident from differences in length of the dorsal fin (Scott and Crossman 1973: in adults, the male dorsal fin usually extends to the adipose fin whereas the female dorsal fin is noticeably shorter) and the swelling of the anal vent and abdomen fullness (gravid) or flaccidity (spent) in females. An undetermined bias was associated with the use of these characteristics as the sole determinant of sex. For example, at the time of sampling, small males may have been classed as juveniles since their dorsal fin may not have reached the adipose and, if unripe or recently spawned, they would not have given milt.

The percentage of mature Arctic grayling by sex was recorded by length class and by age group. Since more than one length or age category had mature fish, probit analysis (Finney 1971) was used in 1989 to estimate the length (LM_x) and age (AM_x) at which various percentages (1% ≤ x ≤ 99%) of the fish were mature (Ridder 1990). For stratification of tagged and recaptured fish and the estimation of mixing rates, fish were classed as mature (adults) if they were equal to or greater than the estimated LM₅₀ and AM₅₀, 289 mm FL and age 6, respectively. All other fish were classed as juveniles.

Sex ratios were presented as the ratio of the number of males to females when initially captured. The proportion of each sex and associated variances were estimated using:

$$\hat{p}_i = a_i/n \quad (1)$$

$$V(\hat{p}_i) = \hat{p}_i(1-\hat{p}_i)/(n-1) \quad (2)$$

where:

\hat{p}_i = the estimated proportion of Arctic grayling of sex i;

a_i = the number of Arctic grayling of sex i; and,

n = the total number of mature Arctic grayling.

Estimation of Age and Size Composition

Estimates of age and size composition of the Arctic grayling populations sampled with electrofishing gear have been shown to be biased (Clark and Ridder 1990). Bias from hook and line sampling, the predominant gear type in this study, is implied but has never been tested. The detection of size bias of both gear types was tested with mark-recapture techniques, which utilize a series of Kolmogorov-Smirnov (K-S) two-sample tests. This procedure has been applied successfully in a number of studies of different Arctic grayling populations in interior Alaska (Clark and Ridder 1990) and are outlined in Appendix B1. In this study, it was applied only to spring samples of mature Arctic grayling as these could be stratified into two events (the mark and the recapture) which occurred over a short time interval in discrete, small spawning areas. Since immature Arctic grayling in these samples were a distinct minority (Table 1), bias in population composition due to behavior and maturity was eliminated by limiting the population to adult fish. Due to time and manpower restraints, summer and fall samples were all single events and therefore, the bias detection technique was not applicable.

The procedure was found applicable in only two of the spring samples: Tundra Pond and the middle thoroughfare of Long Tangle Lake. Size selectivity was inferred in the hook and line sample from the Tundra Pond during the first event but not the second event so age and size composition estimates were derived from the second event ($p = 0.99$ and $p = 0.02$, respectively; Appendices B1 and B2). No size selectivity was inferred in the electrofishing sample from Long Tangle Lake so estimates were derived from pooled events ($p = 0.98$ and $p = 0.83$; Appendices B1 and B3).

In those spring samples where this procedure was not applicable (few or no recaptures) but sampling could be segregated into two or more events, the hypothesis tested was that the size frequencies of each event were similar (the "second" test in Appendix B1). Detection of selectivity bias was then inferred by using the "first" K-S test result (Appendix B1) from one of the

Table 1. Summary of Arctic grayling caught, marked, and recaptured in the Tangle Lakes system, 23 May through 27 August 1990.

			Number of Marks											
			Catch ^a			New		Recaptures ^b						
Location	Location Code	Date	Total	>199mm	Adult	M ^c	M ^d	1986	1987	1988	1989	1990 ^e	Tag loss	Total
Upper Delta River	075	7/3,7/10,7/12	321	281	161	250	135	1	0	5	15	11	0	32
Lower Tangle Lake	101	6/5-6/6	128	128	114	122	107	0	0	3	1	0	1	5
Mid Long Tangle Lake	225	6/4-6/6	352	345	259	318	236	0	0	4	4	0	0	8
Thoroughfare	"	7/11-7/20	151	134	72	120	58	0	0	3	8	3	0	14
Long Tangle Lake Head	251	6/2-6/6	139	139	99	118	83	0	0	2	15	0	0	17
Shallow Tangle Lake	275	6/4,6/6	72	71	54	53	36	0	0	0	18	0	0	18
Thoroughfare														
Landmark Gap Creek	360	7/5,7/10-7/13	323	217	58	199	50	0	0	5	9	5	0	19
"	"	8/21-8/22	307	147	3	141	2	0	0	0	1	5	0	6
18 Mile Creek	391	5/22-5/25,6/4	352	352	317	300	272	2	1	7	28	0	0	38
Upper Tangle Lake	695	5/31	14	14	3	13	3	0	0	1	0	0	0	1
Rock Creek (Upper)	650	6/6,6/7	51	51	51	50	50	0	0	0	0	0	0	0
Rock Creek (Lower)	610	7/4,7/17-7/19	309	172	39	156	27	0	0	3	10	2	2	17
"	"	8/24	43	27	13	0	0	0	0	1	3	6	0	10
Glacier Lake	488	8/19-8/20	103	103	48	91	37	0	0	1	5	0	0	6
Upper Tangle River	710	6/1,6/5	75	22	5	19	3	0	0	0	1	0	0	1
Mud Lake Head	901,903	5/31-6/3	338	250	241	244	163	0	0	3	4	0	0	7
Mud Fork	902	6/1	2	2	1	2	1	0	0	0	0	0	0	0
Upper Mud Lake Head	904	6/3	4	3	2	4	2	0	0	0	0	0	0	0

-continued-

Table 1. (Page 2 of 2).

Totals:	101-904	5/22-6/6	1,527	1,377	1,146	1,237	953	2	1	20	71	0	1	95
	075-610	7/4-7/20	1,104	804	330	725	270	1	0	16	42	21	2	82
	360-610	8/19-8/24	453	330	64	232	39	0	0	2	9	11	0	22
			3,084	2,458	1,540	2,194	1,262	3	1	38	122	32	3	199

^a Adult portion of catch determined by LM₅₀ of 289 mm FL.

^b Recaptures denoted by year of tagging.

^c M = total number of new fish tagged (all >199 mm FL).

^d M = total number of new adult fish tagged.

^e Recaptures made within 6 days of tagging and in same location not included.

above two samples using the same gear type. No biases were detected and all events were pooled in the samples from Mud Lake (three events using hook and line; $0.53 \leq p \leq 0.92$; Appendix B4) and Lower Tangle Lake outlet (two events using electrofishing; $p = 0.87$; Appendix B5). Gear bias was apparent between the Long Tangle Lake electrofishing and hook and line samples ($p < 0.001$; Appendix B6-A) so age and size estimates are presented for both. Unlike the Tundra Pond sample, no size bias was inferred within the hook and line sample ($p = 0.99$; Appendix B6-B) so estimates were from pooled events. The small sample from the second electrofishing event ($n = 6$) precluded a meaningful test and events were pooled. The Rock Creek sample (hook and line) was a single event.

The percent composition for each age class (AC_a) was then estimated as:

$$\hat{AC}_a = \frac{n_a}{n_{AC}} (100) \quad (3)$$

where: n_a = number of Arctic grayling sampled that were age a ; and,

n_{AC} = total number of aged Arctic grayling.

The unbiased variance of this percentage $V[\hat{AC}_a]$ was estimated as:

$$V[\hat{AC}_a] = \frac{\hat{AC}_a(100 - \hat{AC}_a)}{n_{AC} - 1} \quad (4)$$

Two sets of age and size composition estimates are presented in this report. Under the Results section, only those age and size composition estimates derived from spring samples of mature Arctic grayling, corrected for bias, are given. Uncorrected age and size estimates derived directly from all Arctic grayling sampled in 1990 are presented in Appendix C stratified by time, location, and gear type.

Mean fork length-at-age (FL_a) was estimated for all sample locations during each sampling period as:

$$\hat{FL}_a = \frac{\sum_{c=1}^{n_{a1}} FL_{ac}}{n_{a1}} \quad (5)$$

where: FL_{ac} = fork length (mm) of Arctic grayling c that is sampled and age a ; and,

n_{a1} = number of Arctic grayling sampled for length l that are age a .

The variance of this mean $V[\overline{FL_a}]$ was estimated as:

$$V[\overline{FL_a}] = \frac{\sum_{c=1}^{n_{a1}} (\overline{FL_{ac}} - \overline{FL_a})^2}{n_{a1}(n_{a1} - 1)}. \quad (6)$$

These estimates are presented in Appendix C.

Relative Stock Density (RSD; Gabelhouse 1984) was estimated for all sampled Arctic grayling stratified by time, location, and gear type. These are presented in Appendix C. The five RSD length categories (RSD_j) were estimated as:

$$RSD_j = \frac{n_j}{n_{RSD}} (100) \quad (7)$$

where: n_j = number of Arctic grayling sampled that are within RSD length category j ; and,

n_{RSD} = total number of Arctic grayling sampled that are greater than 149 mm FL (minimum stock size).

The unbiased variance of this percent $V[RSD_j]$ was estimated as:

$$V[RSD_j] = \frac{RSD_j(100 - RSD_j)}{n_{RSD} - 1}. \quad (8)$$

The five RSD categories for Arctic grayling were: (1) "stock" 150 mm to 269 mm FL; (2) "quality" 270 mm to 339 mm FL; (3) "preferred" 340 mm to 449 mm FL; (4) "memorable" 450 mm to 559 mm FL; and (5) "trophy" 560 mm FL and greater.

Estimation of Abundance

Spring population abundance of mature Arctic grayling in 1990 was estimated in the Tundra Pond of 18 Mile Creek with the modified Petersen formula of Chapman (1951):

$$N = \frac{(M + 1)(C + 1)}{(R + 1)} - 1 \quad (9)$$

where: M = the number of Arctic grayling marked and released alive during the first event;
 C = the number of Arctic grayling examined for marks during the second event;

R = the number of Arctic grayling recaptured in the second event; and,
 \hat{N} = the estimated abundance of Arctic grayling.

The variance of the estimate was calculated as:

$$\hat{V}[N] = \frac{(M + 1) (C + 1) (M - R) (C - R)}{(R + 1)^2 (R + 2)} . \quad (10)$$

Spring population abundance of mature Arctic grayling was also estimated in the thoroughfare at mid Long Tangle Lake with the modified Petersen formula of Bailey (1951, 1952):

$$\hat{N} = \frac{M (C + 1)}{(R + 1)} . \quad (11)$$

The variance of this estimate was calculated as:

$$\hat{V}[N] = \frac{M^2 (C + 1) (C - R)}{(R + 1)^2 (R + 2)} . \quad (12)$$

The Bailey estimator was used since the assumption of a random sample in the second event was violated. The electrofishing sampling design does not allow for complete mixing of marked and unmarked fish along the entire length of the thoroughfare. However, since the sampling was systematic, it was assumed that localized mixing occurred and that the proportion of fish marked did not change along the length of the thoroughfare.

The abundance of females (or males) in the populations was estimated using:

$$\hat{N}_i = \hat{p}_i \hat{N} \quad (13)$$

where:

\hat{N}_i = the estimated abundance of Arctic grayling of sex i; and,

\hat{p}_i = the proportion of sex i (from equation 1).

The variance of the product \hat{N}_i will be estimated using Goodman's (1960) exact variance of products:

$$\hat{V}(\hat{N}_i) = [N^2 \hat{V}(\hat{p}_i) + \hat{p}_i^2 \hat{V}(\hat{N}) - \hat{V}(\hat{p}_i) \hat{V}(\hat{N})] . \quad (14)$$

The necessary assumptions for an accurate estimate are (from Seber 1982):

- 1) the Arctic grayling population in the study area must be closed;
- 2) no tags can be lost between samples;

- 3) all Arctic grayling have the same probability of capture during the first sample or during the last sample or marked Arctic grayling must completely mix with unmarked Arctic grayling between samples;
- 4) marking must not influence behavior between samples; and,
- 5) mortality is the same for both marked and unmarked fish between samples.

While Arctic grayling populations in the spring are highly mobile in moving between overwintering, spawning, and feeding areas, the population in the Tundra Pond and Long Tangle Lake can be considered closed in this instance. The experiment was conducted over a short time period, four and three days, respectively, on mature fish at spawning sites. Movement of mature fish through the area to upstream spawning or feeding sites was unlikely. During a similar spawning period in the Tundra Pond in 1989, Ridder (1990) observed no fish in upstream areas nor did he capture upstream migrants until 5 June. While in- and out-migration of adults is plausible, it can be considered minimal due to the fish's known behavior. Tack (1980) found movement to spawning sites commencing at 1°C and spawning beginning at 4°C. With water temperatures in the Tundra Pond during the period ranging from 4 to 7°C, it is assumed that all fish destined to spawn in the pond were present. The double marking (partial fin clip and tag) satisfied the second assumption. The third and fourth assumptions were tested with K-S two sample tests (Appendices B1 and B2). The short time interval and the exclusion of visibly injured fish from the experiment minimized the violation of the last assumption.

Estimation of Mixing Rates

The release and recapture of tagged fish allows the tracking of movement of Arctic grayling. Temporal and spatial mixing rates can be estimated from the tagging information. A mixing rate is the probability that a fish tagged and released in Location A during Time B is recovered in Location C during Time D. Mixing rate can be treated as a Markov chain, such that the cell in the transition matrix is an element of a multinomial proportion:

Release Location:	Recapture Location:		
	A	B	C
A	.5	.2	.3
B	.1	.7	.2
C	.3	.3	.4

The marginal proportions in this multinomial distribution were calculated from the following equation:

$$\hat{Q}_{de} = \frac{r_{de}}{r_d} \quad (15)$$

where:

r_d = the total number of recaptured Arctic grayling that were marked in section d;

r_{de} = the number of Arctic grayling marked in section d and recaptured in section e; and,

\hat{Q}_{de} = the relative mixing rate of Arctic grayling tagged in section d and recovered in section e.

The variance of this proportion was estimated as in Equation 4 with the appropriate substitutions.

The Tangle Lakes system was partitioned from 12 sections (Appendices D1 and D2) into six sections in order to maximize numbers of recaptures. These are considered to be the minimum number that will still provide meaningful data on movements. They are, proceeding upstream:

- Area 1: Lower System; Upper Delta River through Round Tangle Lake;
- Area 2: Clear/18 Mile Creek drainage;
- Area 3: Landmark Gap Creek drainage;
- Area 4: Tangle River;
- Area 5: Rock Creek drainage (includes Glacier Lake);
- Area 6: Upper System; a: Upper Tangle River through Mud Lake, and
b: Upper Tangle Lake.

Area 6 was subdivided only for defining recaptures from spring tagging because of distinct differences in recapture locations between locations. No spawning occurs in Upper Tangle Lake but does occur in Mud Lake. A large number of fish were marked and released in Upper Tangle Lake that were captured off the mouth of Rock Creek during the latter part of the spring spawning period (Appendix D2).

Relative mixing rates of Arctic grayling throughout the six sections of the Tangle Lakes system were estimated based on all fish recaptured since 1986. By considering only recaptured fish, grouping of data across years was possible. Due to the known migratory habits of Arctic grayling and unequal recapture efforts in various sections by the sampling crews and anglers, recaptures were stratified in three ways: source (either test, harvest sampling, or voluntary angler returns); time of marking; and time of recapture. The three temporal strata were spring, 16 May through 15 June; summer, 16 June through 15 August, and; fall, 16 August through 30 September. This stratification resulted in 18 transition matrices each containing 36 cells, i.e., seasonal recaptures of all spring, summer, and fall tagging stratified by source. Summaries of the numbers within these matrices (totaled and by maturity) are presented in Appendices D3 through D5.

Since not all feeding aggregations were targeted during test sampling ($n = 5$), recoveries of tagged fish by anglers can be an important source of information for movement and exploitation data. To increase voluntary reporting by anglers in 1990, a poster and map explaining the research project and the desired information (date, specific capture location, tag number and color) were conspicuously placed at both the boat ramp and central information board at each campground, at the bridge over Rock Creek, at the trail heads to Landmark Gap and Glacier Lakes, and at both nearby lodges. A drop box was included with coin envelopes and pencils. Anglers were directed to either leave the information in the box, drop it off at one of the lodges, or inform an Alaska Department of Fish and Game office. The boxes were checked at least monthly. Informational letters were sent to all addressed reports. All addressed reports that were not specific to capture location were sent a letter with enclosed map and postcard requesting the information.

RESULTS AND DISCUSSION

A total of 3,084 Arctic grayling was sampled from 12 locations within the Tangle System in 1990. Fifty percent of these ($n = 1,540$) were adult sized fish (Table 1). The sample included 199 recaptures of fish marked since 1986. A total of 2,194 fish were newly tagged and fin-clipped and included fish that had previously lost their tag. Anglers reported catching 139 tagged fish from which 128 reports were specific to location caught (eight recaptures came from the lower Delta River). Fifty-eight percent of these reports ($n = 80$) were found in the 10 tag return boxes located at main access points.

Due to the distribution of larger Arctic grayling in areas unsuitable for other gear types, the majority of sampling was done by hook and line ($n = 2,330$). Seining captured 173 fish, predominantly small fish during spring sampling from the Upper Tangle River ($n = 65$) and the head of Mud Lake ($n = 108$). A gill net was used in Glacier Lake during a lake trout project and incidentally captured 103 Arctic grayling. High water levels over a six day period allowed access for an electrofishing boat throughout the Tangle System during spring sampling resulting in a catch of 567 Arctic grayling with 3.8 hours of effort. The majority of this effort (3 hrs and 549 fish) was expended around the thoroughfares between Shallow Tangle Lake and the outlet to Lower Tangle Lake (the head of the Delta River). The remaining effort was evenly divided between the head of Mud Lake and the Upper Tangle River with catches of eight and 10 fish, respectively (capture rate suffered in the latter areas due to gear malfunctions). During the same time interval, electrofishing the entire length of the Upper Tangle River between Upper Mud and Mud lakes with a back-pack unit yielded 14 Arctic grayling for 0.5 hours of effort (high velocities and algae-covered cobble decreased the crews' efficiency).

Spring Sampling Summary

Spring sampling (22 May through 7 June) produced the highest proportion of adult-sized Arctic grayling during open water sampling (see Appendix C1). Over 70% ($n = 1,146$) of the 1,527 Arctic grayling sampled were adult sized fish. Concentrations of gravid, ripe, and/or spent fish were located at 17

specific sites within three broad areas of the system which are outlined in Figure 1. Determination of these sites as spawning locations depended primarily on qualitative interpretations of fish distribution, maturity, composition, and behavior as well as substrate type and water temperatures. Armstrong (1982) described Arctic grayling spawning behavior that commenced at temperatures of 4°C and the preferred spawning habitat as riffle areas with a substrate of fine gravel. Ridder (1983, 1989a) offered evidence that spawning is essentially complete when temperatures exceed 10°C. Actual spawning was observed at only one site.

Lower System:

Nine sites were found in four locations within the lower system (below Tangle River; Figure 3). All sites were characterized by localized concentrations of fish, a large proportion of adults in the catches, the presence of ripe individuals, and afternoon temperatures during sampling ranging from 4 to 8°C. Two sites, the Tundra Pond of 18 Mile Creek and the head of Long Tangle Lake, were first located and sampled in 1989 (Ridder 1990). Sampling the other locations, the thoroughfares in mid-Long Tangle Lake and the outlet to Lower Tangle lake, over a three day period consistently located fish in the same sites and no others.

Confounding the description of these latter sites as discrete spawning areas were two recaptures of fish tagged a few days previous. A fish marked in the upper thoroughfare of Long Tangle Lake was recaptured a day later approximately 500 m downstream in the larger thoroughfare. A fish tagged on 25 May in the Tundra Pond was recaptured on 1 June at the head of Long Tangle Lake. The former recapture could have been displaced by handling. The latter recapture was a post-spawner most likely in transit to a feeding area. The Tundra Pond warms earlier than the other areas: afternoon temperatures from 4 to 6 June ranged from 11 to 12°C in the Tundra Pond and ranged from 6 to 8°C at other locations. Thus spawning is essentially finished in the Tundra Pond while still occurring at the other sites.

Upper System:

Five sites were located in the upper Tangle System (Figure 4). Although adult Arctic grayling were either observed and/or sampled at each, it was difficult to determine if they were actually on spawning grounds. Due to small sample sizes, the spent condition of adults, high water temperatures, and/or movements, it can only be assumed that these fish spawned in the upper system.

Mud Fork, a small tributary to Mud Lake, was surveyed along its lower 3 km on 25 May and large Arctic grayling, approximately 20 fish, were found in one area at the head of a pool (a 0.6 m deep run over a substrate of fine gravel). The water temperatures was 7°C and some fish appeared to be displaying territorial behavior. Hook and line sampling was unsuccessful. On 3 June, a return trip recorded a temperature of 9°C and only a few fish in the run. Sampling caught two fish (one being a spent adult) in the pool below.

At the other sites in the Mud Lake area (Figure 4), afternoon temperatures climbed from 10°C on 31 May to 16°C on 3 June. Fish distribution and

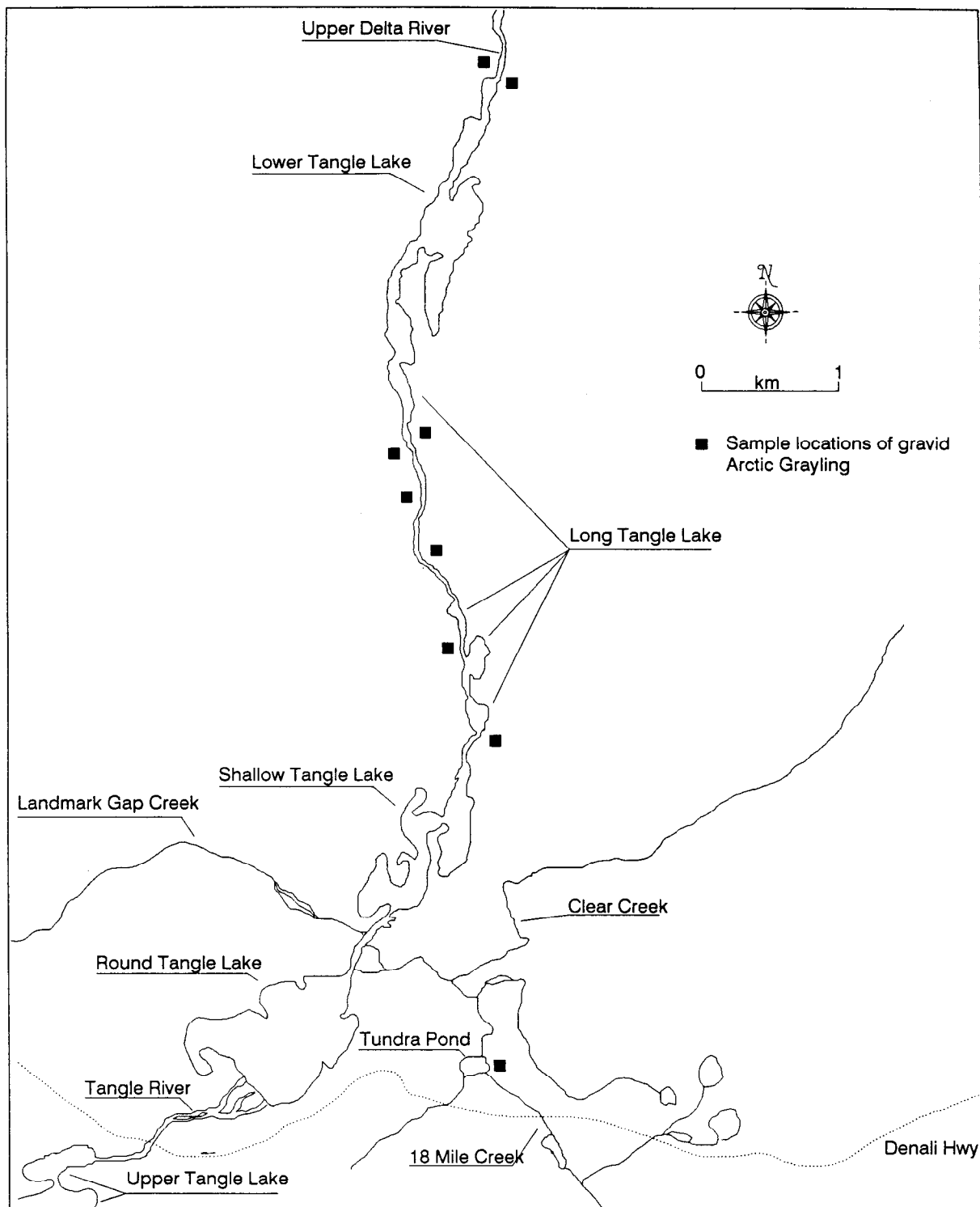


Figure 3. Capture locations of Arctic grayling in the lower Tangle Lakes system, spring 1990.

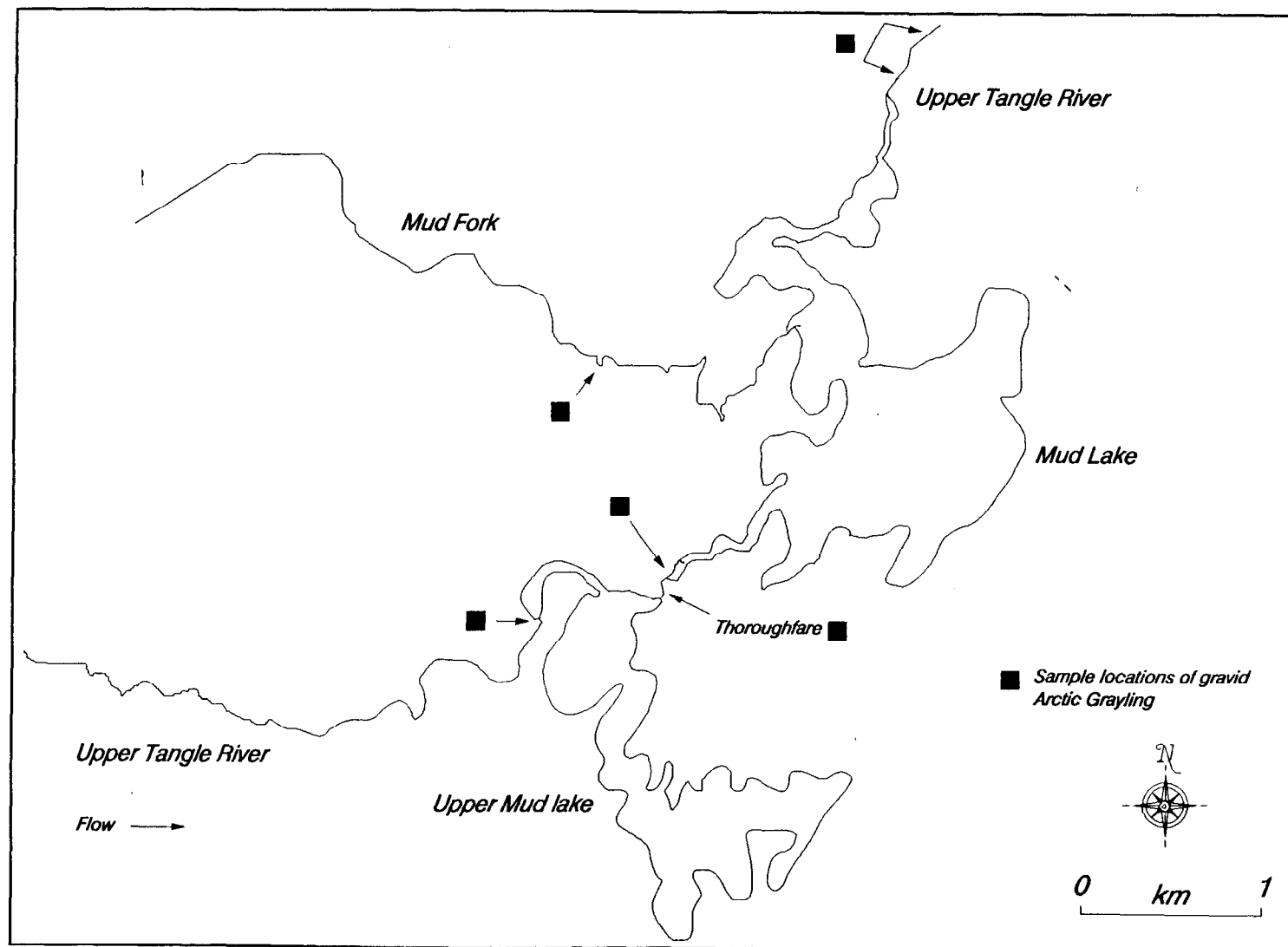


Figure 4. Capture locations of Arctic grayling in the upper Tangle Lakes system, spring 1990.

abundance changed over time and differed from observations and sampling in 1989. The head of Mud Lake and the short thoroughfare connecting it to upper Mud Lake was first sampled on 31 May with most fish being caught at the head. During subsequent sampling on 1 and 3 June, the reverse was true. Arctic grayling were abundant in the thoroughfare along with spawning longnose suckers. Catches included not only adult Arctic grayling marked on 31 May at the head of Mud Lake (these fish had to traverse a beaver dam) but also a high number of immature fish. These sampling conditions and results contrast with those of 31 May 1989 when water temperature was 4.5°C, all fish sampled at the head were mature (ripe and/or gravid), and no fish were observed in the thoroughfare (Ridder 1990 and field notes).

The Upper Tangle River between Mud and Upper Tangle lakes is likely not a spawning location. Spring sampling and observations in 1989 (Ridder 1990) and 1990 lacked the preponderance of mature fish found in the other areas. Over 90% of the grayling sampled in both years were sub-adult sized fish. In contrast, the proportion of sub-adults in the other areas ranged from 0 to 29% (Appendix D1)

Rock Creek:

Three sites were found in Upper Rock Creek (Figure 5): the head and mouth of that section of Rock Creek between Omega and Longspur lakes and a 300 m reach directly above Phalarope Lake. No fish were observed when the remainder of Rock Creek upstream from Phalarope to Longspur lakes was sampled. Late afternoon temperatures were 7 and 9°C on 6 and 7 June, respectively. All captured fish were classified as ripe adults.

Spawning fish were observed at the Longspur site on 7 June. From 11:00 to 16:00 hours, only males were observed or captured in a 0.3 to 1 m deep 10 m long run that had a substrate of fine gravel. Territoriality was not observed until approximately 16:00 hours, when one female moved into the site. Several males then actively chose and defended territories (approximately 2 by 3 m). The female chose one male's area and after repeated defenses of his area from other suitors, the pair spawned. The display lasted approximately 20 minutes.

The Glacier Lake drainage is the major tributary to Rock Creek. The lower kilometer of the lake's inlet was surveyed on 8 June. Ice still covered the lake with the exception of a small area around the inlet. The inlet's water temperature was 3.5°C at 1500 hrs. The reach surveyed consisted of a series of beaver dams that, in places, split the creek into a number of channels. Despite good visibility and the presence of suitable spawning areas (shallow runs of fine gravel were common between pools), no fish were sighted in the creek or at its mouth. Additional and more extensive surveys should be conducted during higher water temperatures to determine if the creek is a spawning area.

Summer Sampling Summary

Summer sampling was conducted 3 through 20 July and utilized hook and line exclusively. A total of 1,104 Arctic grayling was captured in four locations:

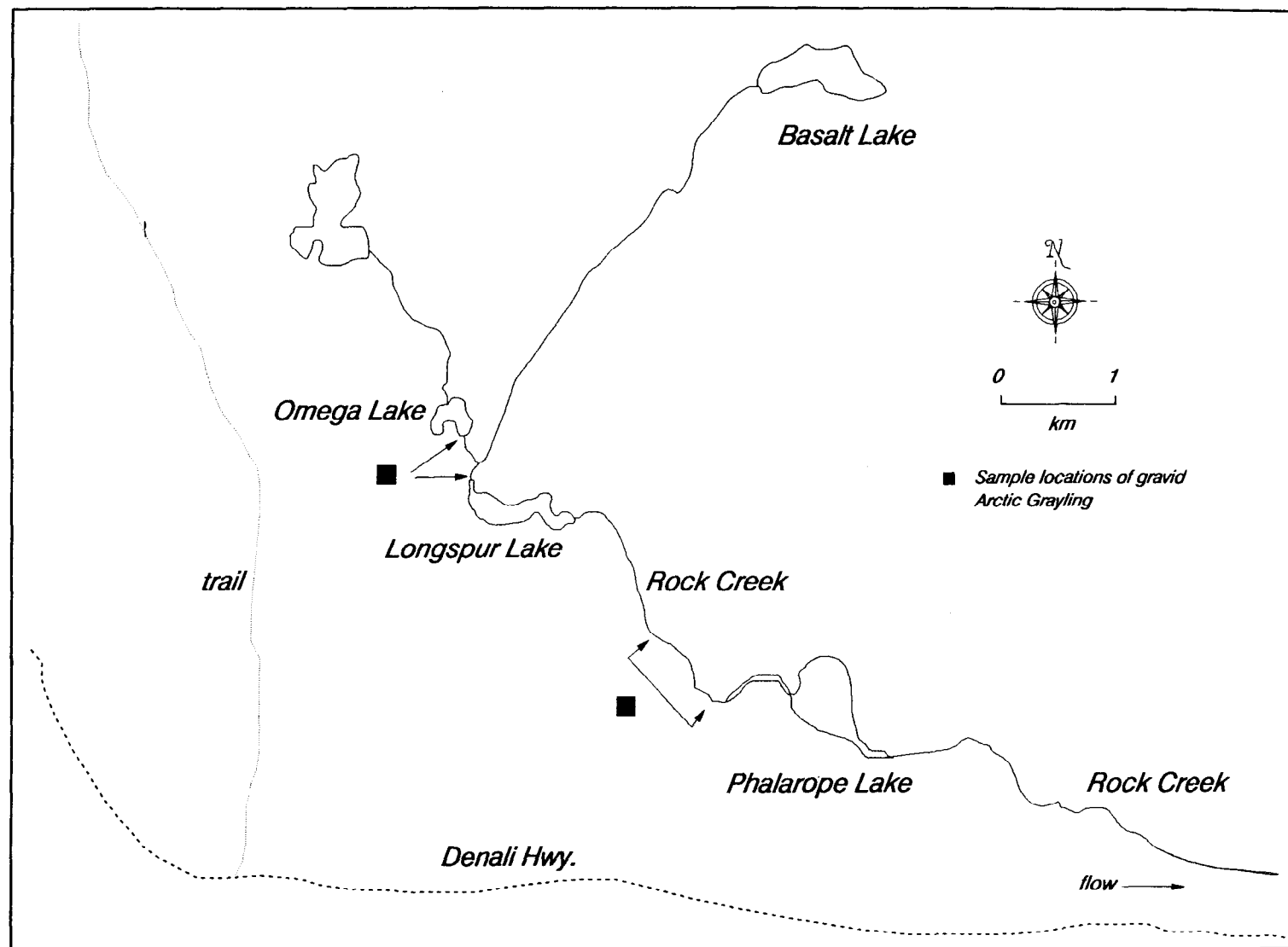


Figure 5. Capture locations of Arctic grayling in upper Rock Creek, spring 1990.

Rock and Landmark Gap creeks, the thoroughfare in mid Long Tangle Lake, and the Upper Delta River (Table 1). Rock Creek was sampled along a 10 km reach from the river mouth upstream to a point approximately 5 km above the Denali Highway crossing. Landmark Gap Creek, the thoroughfare in mid-Long Tangle Lake, and Upper Delta River were sampled in their entirety.

As in 1989, fish in these feeding areas were comprised of a wider range of lengths and also a smaller proportion of adult-sized Arctic grayling than found at spawning areas. While the spring sample consisted of over 75% adults, the summer sample contained 30% ($n = 330$; Table 1). Of the four summer samples, the Upper Delta River and Long Tangle Lake thoroughfare samples contained the highest proportion of adult-sized fish, approximately 50% of each sample (Figure 6). These percentages were similar to the proportions found in 1989 (Appendix D1). The proportion of adults in the samples from Landmark Gap and Rock creeks were much less, 18 and 13%, respectively. Despite similarities in timing and stream reach sampled, these proportions were approximately half of those found in 1989 (39 and 28%, respectively; Appendix D1).

Fall Sampling Summary

Fall sampling occurred from 19 through 24 August in Glacier Lake and Landmark Gap and Rock creeks. The entire reach of Landmark Gap Creek and a 2 km reach of Rock Creek upstream of the Denali Highway were sampled. The latter two areas were sampled to increase the number of adults and recaptures over that obtained during summer sampling but efforts met with limited success. A total of 453 Arctic grayling was sampled yet included only 14% adults ($n = 64$; Table 1; Figure 7). Adults were rare in the Landmark Gap Creek sample (three adults out of 307 fish or 1%). The adults in the Glacier Lake sample, while comprising 47% ($n = 48$), was well below the 79% found in the July 1989 sample (Appendix D1). The Rock Creek sample contained over twice the number of adults as the summer sample but the proportion was likely influenced by both the short reach and small sample size.

Sex and Maturity

Sex was determined for 985 (66%) of all Arctic grayling caught during spring sampling. The ratio of males to females, 1.8:1 for the total sample, varied considerably between locations (Table 2) and compares to 1.1:1 estimated in 1989 (Ridder 1990). Variation in sex ratio appeared to be affected by vulnerability to gear type. Electrofishing samples had ratios ranging from 4.6 to 10.0:1 compared to a range of 0.7 to 2.8:1 for hook and line samples. Pooled, electrofishing samples contained significantly more males than hook and line samples (5.7:1 and 1.1:1, respectively ($\chi^2 = 111.01$, $df = 1$, $p < 0.05$)). A plausible hypothesis can be related to behavior of adult Arctic grayling and their vulnerability to different gears. Throughout the spawning period, males locate themselves on the spawning grounds in and immediately below riffle areas which are usually less than 1 m deep and females, while not actually spawning, are in adjacent pools (Tack 1980; Warner 1955a). Electrofishing is most efficient in shallow water, riffle areas and much less so in pools. Hook and line can be equally efficient in all depths and water types. Both gear types were used at the spawning site at the head of Long

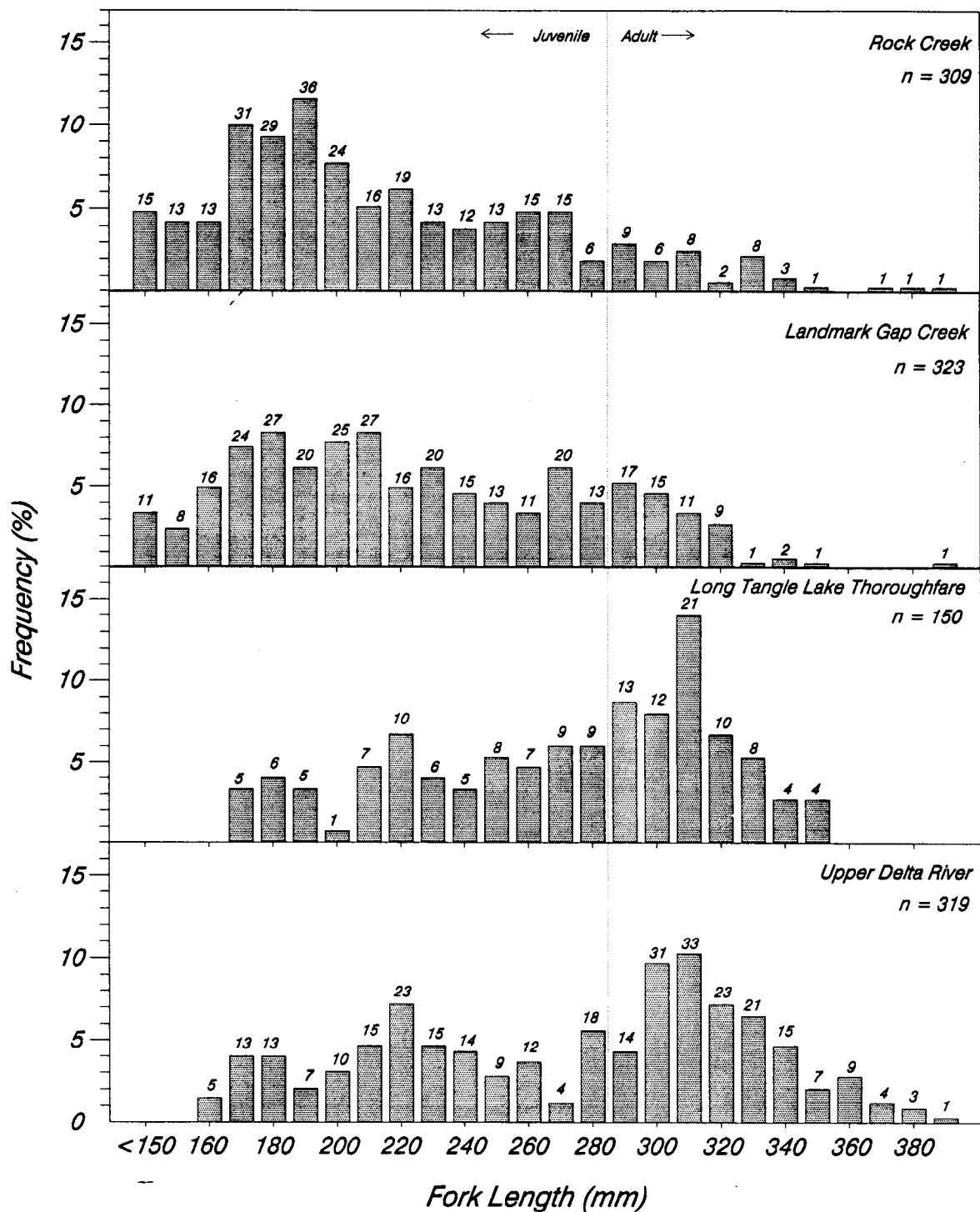


Figure 6. Comparison of the length frequencies of Arctic grayling in 10 mm FL groups sampled from four summer feeding locations in the Tangle Lakes system, July 1990. Sample sizes are shown above the bars.

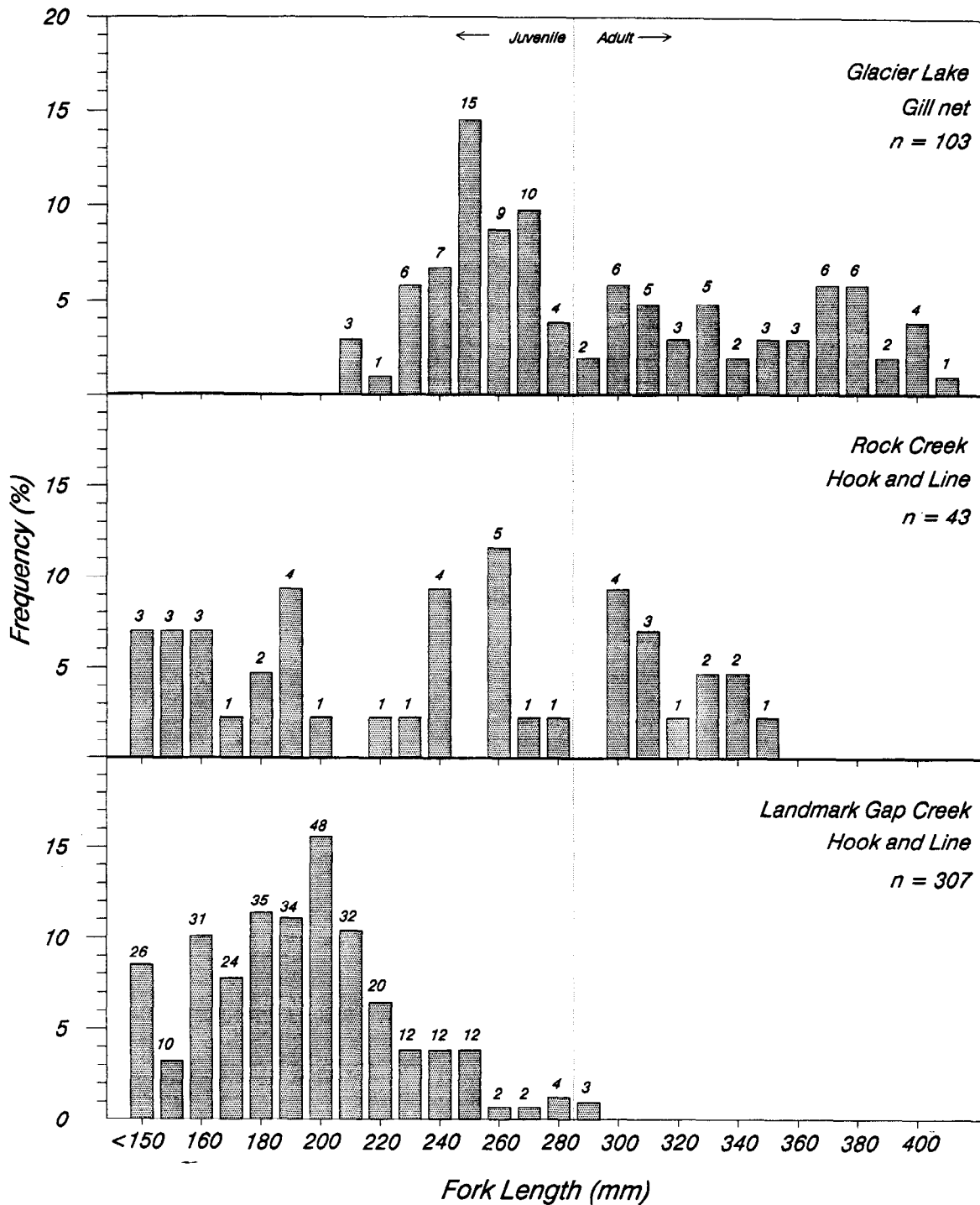


Figure 7. Comparison of the length frequencies of Arctic grayling in 10 mm FL groups sampled from three summer feeding locations in the Tangle Lakes system, August 1990. Sample sizes are shown above the bars.

Table 2. Sex ratios (male:female) of mature^a Arctic grayling by location and gear type in the Tangle Lakes system, 22 May through 7 June 1990.

Location	Gear ^b	N ^c	Males			Females			Ratio
			n ^d	% ^e	SE ^f	n	%	SE	
Lower Tangle Lake	EB	110	100	91	3	10	9	3	10.0 : 1
Long Tangle Lake	EB	223	183	82	3	40	18	3	4.6 : 1
Long Tangle Lake Head	EB	55	47	86	5	8	15	5	5.9 : 1
Long Tangle Lake Head	HL	99	56	57	5	43	43	5	1.3 : 1
Tundra Pond	HL	289	151	52	3	138	48	3	1.1 : 1
Mud Lake	HL	141	58	41	4	83	59	4	0.7 : 1
Rock Creek	HL	50	37	74	6	13	26	6	2.8 : 1
others	misc	18	2	11	7	16	89	7	0.1 : 1
Totals		985	634	64	2	351	36	2	1.8 : 1

^a Maturity determined by sexual dimorphism or sexual products.

^b EB = electrofishing boat; HL = hook and line; misc. = EB + HL + seine.

^c N = total catch.

^d n = number in group.

^e % = percent in group.

^f SE = sample standard error for the percentage.

Tangle Lake. Electrofishing produced a sex ratio of 5.9:1 while hook and line gave a ratio of 1.3:1 (Table 2). Although electrofishing had equal catchability among sexes (see Abundance section below), female Arctic grayling are not vulnerable to capture by electrofishing when residing in deep pools.

Length composition was significantly different between mature males and females (K-S test: $p < 0.01$, Figure 8; $\chi^2 = 73.42$, $df = 5$, $p < 0.01$). As found in 1989 (Ridder 1990) and in the spawning stocks in Mineral Lake outlet and Goodpaster River (Ridder 1989a, 1989b), the male population contained more larger individuals than females.

Due to differential vulnerability towards males and their larger length, the length composition of all mature fish was significantly different than that estimated in 1989 (K-S test: $p < 0.01$, Figure 9; $\chi^2 = 23.10$, $df = 7$, $p < 0.01$; the Rock Creek sample was excluded in this analysis due to significant compositional differences).

Mature fish were first detected at lengths of 250 to 259 mm FL and age 4 (Tables 3 and 4). All fish were classified mature above a length of 370 mm and at age 9. The maturity schedule for length was wider than in 1989. While the schedule for ages was narrower than in 1989, it was not significantly different (270 to 330 mm FL; ages 4 to 8; Ridder 1990).

Age Composition

Age composition estimates for mature Arctic grayling were derived for seven samples from six locations (Table 5) but small sample sizes and sex bias provided only general comparisons between areas. With the exception of the upper Rock Creek sample, ages can be considered similar and ranged from age 4 to age 9 with the predominant age being age 6 in each sample. This is essentially unchanged from 1989 data.

The Rock Creek sample was notably different than other areas by containing much older fish. Ages ranged from age 6 to age 10 with age 8 having the highest proportion. As such, the Rock Creek sample is excluded from compositional analyses of all pooled samples mentioned in this report.

Gear type affected the composition estimates with electrofishing catching fewer young fish (1 to 7% were age 5 with no age 4's; Table 5) than hook and line (7 to 12% were ages 4 and 5). The pooling of gear samples resulted in age compositions (grouped into three classes: ages 4 and 5, age 6 and age 7 and older) which were significantly different ($\chi^2 = 23.13$, $df = 2$, $p < 0.05$). The difference maybe a result of the sex bias induced by differential vulnerability to electrofishing gear.

Although differences were found in age composition between areas in the Tangle Lakes, these were assumed to be due to natural variability in age composition and the aforementioned sampling bias by sex. However, a general view of age composition by sex for the Tangle Lakes system can be made by pooling all samples (excluding Rock Creek). Their individual and combined compositions were unchanged from those reported in 1989 (Ridder 1990). Although age 6 was predominant and similarly proportioned in both sexes, males had significantly

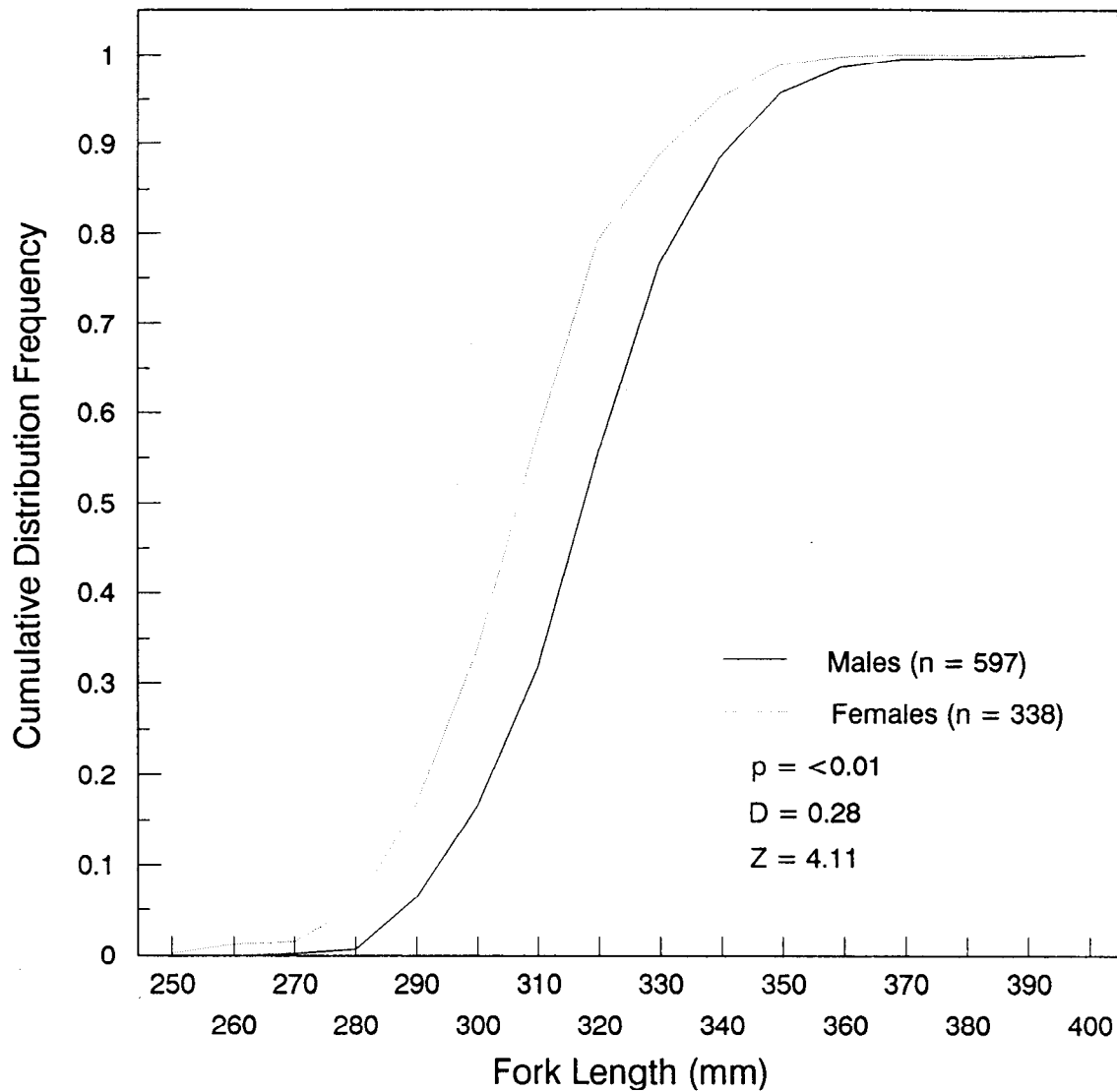


Figure 8. Cumulative distribution function of lengths of mature male Arctic grayling versus lengths of mature female Arctic grayling in the Tangle Lakes system (Rock Creek excluded), 22 May through 6 June 1991. Statistics are from the Kolmogorov-Smirnov two-sample test.

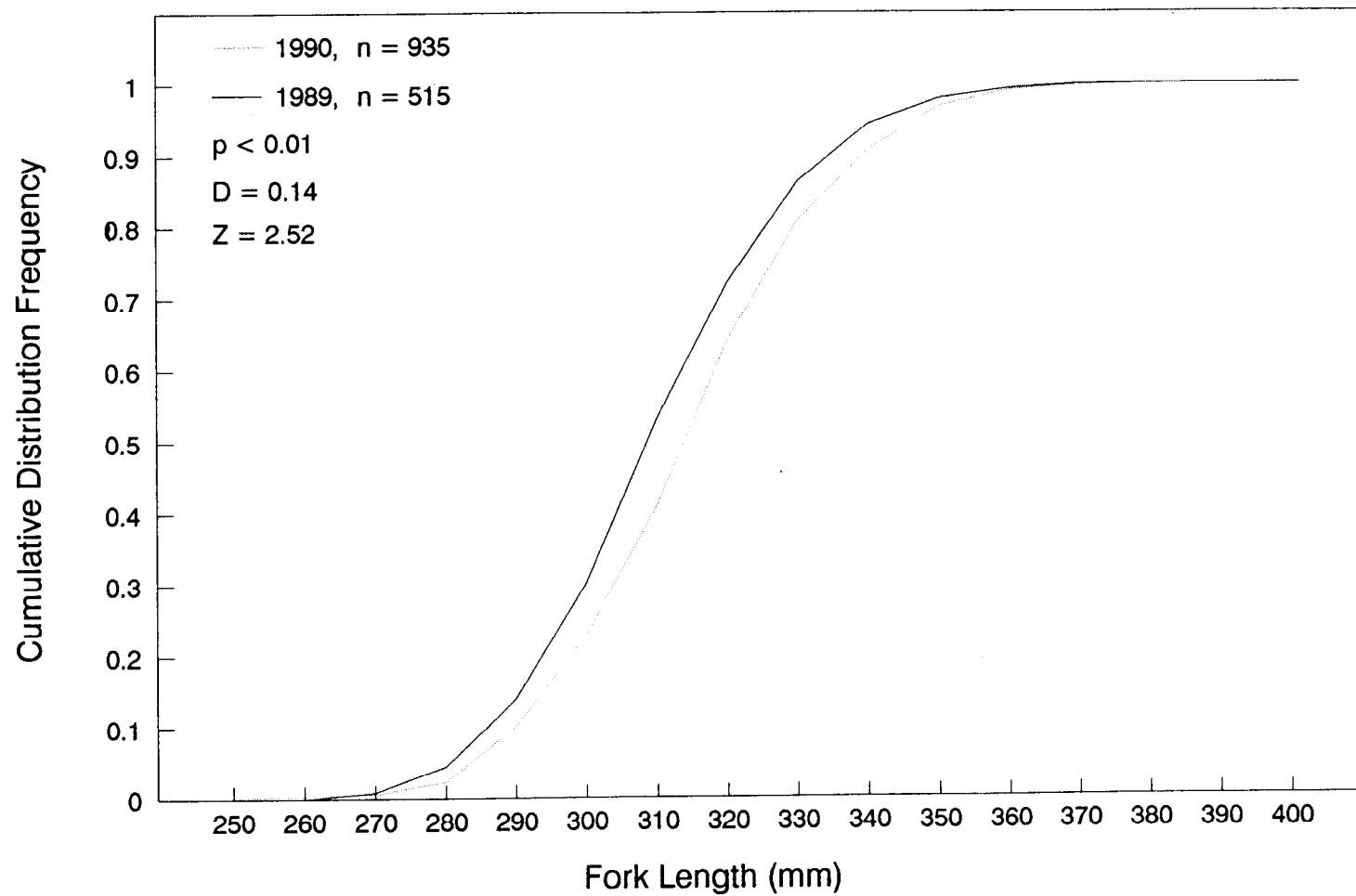


Figure 9. Cumulative distribution function of lengths of mature Arctic grayling captured in 1989 versus those captured in 1990 in the Tangle Lakes system (Rock Creek excluded). Statistics are from the Kolmogorov-Smirnov two-sample test.

Table 3. Percent mature^a Arctic grayling in 10 mm FL groups sampled from seven locations^b in the Tangle Lakes system, 22 May through 6 June 1990.

10 mm Group	N ^c	Mature		
		n ^d	% ^e	SE ^f
<200	150	0	---	---
200 - 209	19	0	---	---
210 - 219	29	0	---	---
220 - 229	28	0	---	---
230 - 239	39	0	---	---
240 - 249	32	0	---	---
250 - 259	36	1	2.8	2.7
260 - 269	37	3	8.1	4.5
270 - 279	33	2	6.1	4.2
289 - 289	50	16	32.0	6.6
290 - 299	119	73	61.3	4.5
300 - 309	145	118	81.4	3.2
310 - 319	180	170	94.4	1.7
320 - 329	222	216	97.3	1.1
330 - 339	158	156	98.7	0.9
340 - 349	94	93	98.9	1.1
350 - 359	60	57	95.0	2.8
360 - 369	21	20	95.2	4.6
370 - 379	7	7	100.0	---
380 - 389	1	1	100.0	---
390 - 399	1	1	100.0	---
400 - 409	1	1	100.0	---
Totals	1,462	935	64.0	1.3

^a Maturity determined by sexual dimorphism or sexual products.

^b 18 Mile and Clear creeks, Heads of Mud, Upper Tangle, and Long Tangle lakes, Long Tangle Lake Thoroughfare, and Lower Tangle Lake Outlet.

^c N = total catch in group.

^d n = number mature in group.

^e % = percent mature in group.

^f SE = sample standard error for the percentage.

Table 4. Percent mature^a Arctic grayling in age classes sampled from seven locations^b in the Tangle Lakes system, 22 May through 6 June 1990.

Age Class	N ^c	Mature		
		n ^d	% ^e	SE ^f
1	2	0	---	---
2	44	0	---	---
3	83	0	---	---
4	100	2	2.0	1.4
5	115	50	43.5	4.6
6	487	417	85.6	1.6
7	310	294	94.8	1.3
8	50	49	98.0	2.0
9	8	8	100.0	---
Total	1,199	820	68.4	1.3

^a Maturity determined by sexual dimorphism or presence of gametes.

^b 18 Mile and Clear creeks, Heads of Mud, Upper Tangle, and Long Tangle lakes, Long Tangle Lake Thoroughfare, and Lower Tangle Lake Outlet.

^c N = total catch in age class.

^d n = number mature in age class.

^e % = percent mature in age class.

^f SE = sample standard error for the percentage.

Table 5. Age composition estimates by gear type and location for mature^a Arctic grayling sampled from six locations in the Tangle Lakes system, 22 May through 6 June 1990.

Age Class	Lower Tangle LK 5 June - 6 June Electrofishing			Long Tangle Lk Thoro. 4 June - 6 June Electrofishing			Long Tangle Lk Head 4 June, 6 June Electrofishing			Long Tangle Lk Head 4 June, 6 June Hook and Line			18 Mile Creek 24 May - 25 May Hook and Line			Mud Lake Head 31 May - 3 June Hook and Line		
	n ^b	%	SE ^c	n	%	SE	n	%	SE	n	%	SE	n	%	SE	n	%	SE
1	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
2	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
3	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
4	0	---	---	0	---	---	0	---	---	1	1.3	1.3	0	---	---	1	0.8	0.8
5	1	1.0	1.0	4	2.0	1.0	3	7.3	4.1	8	10.4	3.5	12	6.8	1.9	15	12.3	3.0
6	53	54.6	5.1	96	47.3	3.5	21	51.2	7.8	54	70.1	5.2	78	44.1	3.7	73	59.8	4.4
7	40	41.2	5.0	91	44.8	3.5	13	31.7	7.3	14	18.2	4.4	69	39.0	3.7	29	23.8	3.9
8	3	3.1	1.0	11	5.4	1.6	2	4.9	3.4	0	---	---	15	8.5	2.1	4	3.3	1.6
9	0	---	---	1	0.5	0.5	2	4.9	3.4	0	---	---	3	1.7	1.0	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	97	100.0		203	100.0		41	100.0		77	100.0		177	100.0		122	100.0	

-continued-

Table 5. (Page 2 of 2).

Upper Rock Creek 6 June - 7 June Hook and Line			
Age Class	n	%	SE
1	0	---	---
2	0	---	---
3	0	---	---
4	0	---	---
5	0	---	---
6	4	8.7	4.2
7	8	17.4	5.6
8	22	47.8	7.4
9	11	23.9	6.3
10	1	2.2	2.2
Total	46	100.0	

^a Adults were determined by either sexual dimorphism or presence of gametes.

^b n = sample size.

^c SE = standard error of the percentage.

fewer younger individuals and more older ones than females (for ages 4 and 5, 6, 7, and 8+: $\chi^2 = 16.47$, $df = 3$, $p < 0.05$; Table 6).

The mean fork lengths at age by sex were similar at all locations except Rock Creek, so all samples were combined except for the latter (Appendices C5 and C6). Adult males were significantly larger than females for ages 6 and greater (Table 7). The male sample had a mean length of 327 mm FL (SD = 18 mm; SE = 1 mm), while females had a mean length of 317 mm FL (SD = 18 mm; SE = 1 mm). The mean length of the combined sample was 324 mm FL.

Size Composition

Quality sized fish (270 - 339 mm FL) predominated in all but one sample of mature Arctic grayling ranging from 69% to 91% (Table 8). An exception was the Rock Creek sample where 94% of the sample were fish in the preferred size (greater than 340 mm FL) and 6% in the quality size. Stock sized fish (less than 270 mm FL) were almost non-existent in these spring samples and occurred in only two samples at 2% or less.

As in age composition and length frequencies, there was a significant difference in RSD indices between the sexes ($\chi^2 = 17.44$, $df = 1$, $p < 0.05$). For adult male Arctic grayling, 80% were quality size and 20% preferred size, while adult females were 93% and 7%, respectively (Table 8).

Abundance

The estimated abundance of mature Arctic grayling in the Tundra Pond of 18 Mile Creek was 1,162 fish (SE = 246 fish and $cv = 21\%$; Table 9) and was equally divided among the sexes. Size bias was not detected in the marking event, but tended to favor larger individuals (Appendix B2). Although males were more abundant in the marking event (Table 9), there was no significant differences in the ratio of males to females when the marking ratio was compared to the recapture and capture ratios ($\chi^2 = 1.33$, $df = 1$, $p > 0.05$ and $\chi^2 = 0.07$, $df = 1$, $p > 0.05$, respectively). Hence, stratification by sex was not warranted and the pooled sex composition was used to apportion abundance by sex.

The estimated abundance of mature Arctic grayling in the spawning areas within Long Tangle Lake was 764 (SE = 156 and $cv = 20\%$; Table 10) and was heavily skewed towards males. No size bias was detected but contingency tests inferred a sexual bias in the first event but none in the second (from Appendix B1 and substituting tests; first test: $\chi^2 = 0.53$, $df = 1$, $p > 0.05$ and, second test: $\chi^2 = 5.22$, $df = 1$, $p < 0.05$). Thus, the sex ratio of the second event was used to apportion the abundance estimate. Still, this estimate of adult fish is low if the sex ratio was biased by the capture method as has been suggested. A more accurate, but untestable estimate would be to assume a 1:1 sex ratio and double the abundance of males. Thus, the stock utilizing spawning areas in Long Tangle Lake would be 1,344 Arctic grayling.

Table 6. Age composition estimates and standard errors for mature male and female Arctic grayling sampled from five locations^a in the Tangle Lakes System, 22 May through 6 June 1990.

Age Class	Males			Females			Both		
	n ^b	%	SE ^c	n	%	SE	n	%	SE
4	0	---	---	2	0.7	0.5	2	0.2	0.2
5	21	4.0	0.9	29	9.8	1.7	50	6.1	0.8
6	263	50.2	2.2	154	52.0	2.9	417	50.9	1.7
7	198	37.8	2.1	96	32.4	2.7	294	35.9	1.7
8	36	6.9	1.1	13	4.4	1.2	49	6.0	0.8
9	6	1.1	0.5	2	0.7	0.5	8	1.0	0.3
Total	524	100.0		296	100.0		820	100.0	

^a 18 Mile Creek, Heads of Mud and Long Tangle lakes, Long Tangle Lake Thoroughfare and, Lower Tangle Lake Outlet.

^b n = sample size.

^c SE = standard error of the percentage.

Table 7. Mean fork length at age for mature male and female Arctic grayling sampled from five locations^a in the Tangle Lakes system, 22 May through 6 June 1990.

Age Class	Males			Females			Both		
	n ^b	FL ^c	SD ^d	n	FL	SD	n	FL	SD
4	0	---	---	2	271	7	2	271	7
5	21	308	15	29	301	18	50	304	17
6	263	321	15	154	314	15	417	318	16
7	198	333	14	96	325	15	294	330	15
8	36	350	16	13	342	17	49	348	17
9	6	367	18	2	330	20	8	358	25
Total	524	327	18	296	317	18	820	324	19

^a 18 Mile Creek, Heads of Mud and Long Tangle lakes, Long Tangle Lake Thoroughfare and, Lower Tangle Lake Outlet.

^b n = sample size.

^c FL = mean fork length at age in millimeters

^d SD = sample standard deviation of FL.

Table 8. Summary of Relative Stock Density (RSD) indices for mature Arctic grayling sampled from the Tangle Lakes system by area, gear type and sex, 22 May through 7 June 1990.

		RSD Category ^a				
		Stock	Quality	Preferred	Memorable	Trophy
<u>Lower Tangle Lake Outlet:</u>						
5 June - 6 June						
Electrofishing	n ^b	0	95	14	0	0
	% ^c	---	87.2	12.8	---	---
	SE ^d	---	3.2	3.2	---	---
<u>Long Tangle Lake Thoroughfare:</u>						
2 June - 6 June						
Electrofishing	n	0	175	45	0	0
	%	---	79.5	20.5	---	---
	SE	---	2.7	2.7	---	---
<u>Long Tangle Lake Head:</u>						
2 June - 6 June						
Electrofishing	n	0	35	17	0	0
	%	---	68.6	23.3	---	---
	SE	---	6.5	6.5	---	---
<u>Long Tangle Lake Head:</u>						
2 June - 4 June						
H&L ^e	n	2	90	7	0	0
	%	2.0	90.9	7.1	---	---
	SE	1.4	2.9	2.6	---	---
<u>18 Mile Creek:</u>						
24 May - 25 May						
H&L	n	0	163	31	0	0
	%	---	84.0	16.0	---	---
	SE	---	2.6	2.6	---	---
<u>Upper Rock Creek</u>						
6 June - 7 June						
H&L	n	0	3	47	0	0
	%	---	6.0	94.0	---	---
	SE	---	3.3	3.3	---	---

-continued-

Table 8. (Page 2 of 2).

		RSD Category				
		Stock	Quality	Preferred	Memorable	Trophy
<u>Mud Lake Head:</u>						
31 May - 3 June						
H&L	n	1	114	26	0	0
	%	0.7	80.9	18.4	---	---
	SE	0.7	3.3	3.3	---	---
<u>Totals:</u> ^f						
<u>Males:</u>						
	n	0	456	141	0	0
	%	---	76.4	23.6	---	---
	SE	---	1.7	1.7	---	---
<u>Females:</u>						
	n	4	295	39	0	0
	%	1.2	87.3	11.5	---	---
	SE	0.6	1.8	1.7	---	---
<u>Both</u>						
	n	4	751	180	0	0
	%	0.4	80.3	19.3	---	---
	SE	0.2	1.3	1.3	---	---

^a Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):

Stock - 150 mm

Quality - 270 mm

Preferred - 340 mm

Memorable - 450 mm

Trophy - 560 mm

^b n = sample size in RSD category.

^c % = percent of RSD category in total sample.

^d SE = standard error of percentage.

^e H&L = hook and line.

^f Totals include all mature Arctic grayling captured from 22 May through 7 June in the Tangle Lakes system excluding Rock Creek.

Table 9. Sample sizes and estimated abundance of mature Arctic grayling in the spawning aggregation in Tundra Pond of 18 Mile Creek, Tangle Lakes system, May 1990.

Date	Sample	Size	Males			Females			Ratio ^d
			n ^a	p ^b	SE ^c	n	p	SE	
5/22-5/23	Mark	93	53	0.57	0.05	40	0.43	0.05	1.3:1
5/24-5/25	Catch	197	98	0.50	0.04	99	0.50	0.04	1.0:1
"	Recaptures	15	8	0.53	0.13	7	0.47	0.13	1.1:1
	N ^e	1,162	605			557			
	SE ^f	246	132			123			
	cv ^g	21%	22%			22%			

^a n = number in group.

^b % = percent in group.

^c SE = sample standard error for the percentage.

^d Ratio of males to females.

^e Estimated abundance by Chapman's modification of the Petersen estimator.

^f Standard error of the estimated abundance.

^g The coefficient of variation expressed as a percentage.

Table 10. Sample sizes and estimated abundance of mature Arctic grayling in the spawning aggregation in thoroughfares in Long Tangle Lake, June 1990.

Date	Sample	Size	Males			Females			Ratio ^d
			n ^a	p ^b	SE ^c	n	p	SE	
6/4	Mark	124	95	0.77	0.04	29	0.23	0.04	3.3:1
6/5-6/6	Catch	116	102	0.88	0.03	14	0.12	0.03	7.3:1
	Recaptures	18	15	0.83	0.09	3	0.17	0.09	5.0:1
	N ^e	764	682			82			
	SE ^f	156	141			26			
	cv ^g	20%	21%			32%			

^a n = number in group.

^b % = percent in group.

^c SE = sample standard error for the percentage.

^d Ratio of males to females.

^e Estimated abundance by Chapman's modification of the Petersen estimator.

^f Standard error of the estimated abundance.

^g The coefficient of variation expressed as a percentage.

Mixing Rates

Since 1986, a total of 695 Arctic grayling have been recaptured in known locations from the 7,829 fish that were tagged and released within the Tangle Lakes system above the Delta River falls. While these numbers are large and show considerable mixing of fish throughout the system (Ridder 1990), precision of mixing rate data decreases after stratification into season and source of recapture (Table 11). From Thompson (1987), recaptures should be above 400 for each stratum so that proportions are within 10% of the true proportions 95% of the time. Though imprecise, the data does afford the only available insight into the movements of the fish between their spawning, summer feeding, and overwintering areas.

Mixing of Fish Tagged in Spring:

The hypothesis that Arctic grayling home to spawning areas, while unproven, is accepted based on the available literature (Tack 1980; Ridder *in press*). These areas are also natal areas, and forms the basis for the definition of discrete stocks or populations. Thus, the recaptures of Arctic grayling tagged in the spring in or near spawning areas in the Tangle Lakes system would provide the best data on mixing rates. Unfortunately, the data base on these tagged fish is sparse, dating back to 1989 and with the majority of the tagging coming from 1990 efforts.

Mixing rates of fish tagged in spring varied by location as well as season (Tables 12 through 14). Due to limited sampling locations, test sampling generally gave higher mixing rates in fewer locales than angler reports. Therefore, recapture data from test sampling (in cases where test sampling was not exhaustive) should be interpreted with caution. Fish tagged on spawning grounds below the Tangle River showed limited distribution to summer feeding areas in the river or downstream (Table 13). No recaptures of fish from test sampling or anglers were made in areas above the river. Fish from 18 Mile Creek nearly all emigrated to either the lower system, Landmark Gap Creek or Tangle River while the majority of those from the lower system areas remained within the lower system. In the fall, fish were more apt to be found in the lower system than in other areas (Table 14).

Fish tagged in the upper system utilized the whole length of the Tangle System with the exception of 18 Mile Creek but preferred the upper reaches and Rock Creek. By fall, these fish showed a tendency to move upstream and out of tributaries into the upper system.

One similar mixing rate was found in the angler reports that was common to the three accepted spawning populations. From 22 to 25% of these stocks were found in the summer harvest in the Tangle River (Table 13).

Spring recaptures of fish tagged in spring generally supported the homing hypothesis (Table 13). No mixing between spawning areas of lower system Arctic grayling was found. The mixing of 18 Mile Creek and Mud Lake fish into the lower system is likely an artifact of time of spawning and the arbitrary definition of spring used in this report. In both of the latter areas, water temperatures warm sooner than in the lower system indicating that spawning had

Table 11. Summary of recaptures of Arctic grayling tagged in the Tangle Lakes system by season and origin^a, 1986 through 1990.

Marking		Number of Recaptures									Recapture Rate (%) ^b		
		Spring		Summer		Fall		Totals					
Season	M ^c	Test Angler		Test Angler		Test Angler		Test Angler Both			Test Angler		Both
Spring	2,379	65	35	52	51	16	21	133	107	240	5.6	4.5	10.1
Summer	3,354	41	9	91	56	41	35	173	100	273	5.2	3.0	8.1
Fall	2,096	33	14	56	33	27	19	116	66	182	5.5	3.1	8.7
Totals	7,829	139	58	199	140	84	75	422	273	695	5.4	3.5	8.9

^a Recaptures are from either test sampling or anglers voluntary reports. Test sampling includes harvest sampling.

^b Recapture rate is total recaptures divided by total marked.

^c M = Total number of marks released.

Table 12. Relative mixing rates of all Arctic grayling tagged in the spring and recaptured in the spring at least one year later in the Tangle Lakes system from 1988 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

Spring Recapture Area													
Spring Release Area ^a	Total Recaptures	Lower System		18 Mile Cr		Landmark		Tangle R.		Rock Ck.		Upper System	
		p ^b	SE ^c	p	SE	p	SE	p	SE	p	SE	p	SE
A; from test sampling:													
Lower System	31	1.00	0	0	---	NS ^d		NS		0	---	0	---
18 Mile Creek	28	0.18	0.07	0.82	0.07	NS		NS		0	---	0	---
Rock Creek Drainage	0												
Upper Tangle Lake	4	0	---	0	---	NS		NS		0	---	1.00	0
Mud Lake Head	2	0.50	0.35	0	---	NS		NS		0	---	0.50	0.35
B; from angler reports:													
Lower System	0												
18 Mile Creek	28	0.04	0.04	0.92	0.05	0.04	0.04	0	---	0	---	0	---
Rock Creek Drainage	0												
Upper Tangle Lake	7	0.14	0.13	0	---	0	---	0.43	0.19	0	---	0.43	0.19
Mud Lake Head	0												

^a Area = Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters.

^b p = mixing rate expressed as a proportion.

^c SE = standard error of the proportion.

^d NS = No sampling.

Table 13. Relative mixing rates of all Arctic grayling tagged in the spring and recaptured in the summer in the Tangle Lakes system from 1988 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

Summer Recapture Area													
Spring Release Area ^a	Total Recaptures	Lower System		18 Mile Cr		Landmark		Tangle R.		Rock Ck.		Upper System	
		p ^b	SE ^c	p	SE	p	SE	p	SE	p	SE	p	SE
A; from test sampling:													
Lower System	19	0.95	0.05	NS ^d		0.05	0.05	NS		0	---	NS	
18 Mile Creek	9	0.56	0.17	NS		0.44	0.17	NS		0	---	NS	
Rock Creek Drainage	0												
Upper Tangle Lake	14	0.50	0.13	NS		0.07	0.07	NS		0.43	0.13	NS	
Mud Lake Head	6	0	---	NS		0.33	0.19	NS		0.68	0.19	NS	
B; from angler reports:													
Lower System	9	0.67	0.16	0	---	0.11	0.11	0.22	0.14	0	---	0	---
18 Mile Creek	12	0.42	0.14	0.08	0.08	0.25	0.13	0.25	0.13	0	---	0	---
Rock Creek Drainage	1	0	---	0	---	0	---	0	---	1.00	0	0	---
Upper Tangle Lake	17	0.29	0.11	0	---	0.06	0.06	0.41	0.12	0.24	0.10	0	---
Mud Lake Head	12	0.08	0.08	0	---	0	---	0.25	0.13	0.25	0.13	0.42	0.14

^a Area = Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters.

^b p = mixing rate expressed as a proportion.

^c SE = standard error of the proportion.

^d NS = No sampling.

Table 14. Relative mixing rates of all Arctic grayling tagged in the spring and recaptured in the fall in the Tangle Lakes system from 1988 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

Fall Recapture Area													
Spring Release Area ^a	Total Recaptures	Lower System		18 Mile Cr		Landmark		Tangle R.		Rock Ck.		Upper System	
		p ^b	SE ^c	p	SE	p	SE	p	SE	p	SE	p	SE
A; from test sampling:													
Lower System	4	1.00	0	NS ^d		0	---	0	---	0	---	0	---
18 Mile Creek	0												
Rock Creek Drainage	0												
Upper Tangle Lake	12	0.33	0.14	NS		0	---	0	---	0	---	0.67	0.14
Mud Lake Head	0												
B; from angler reports:													
Lower System	5	0.80	0.18	0	---	0.20	0.18	0	---	0	---	0	---
18 Mile Creek	7	0.86	0.13	0	---	0	---	0.14	0.13	0	---	0	---
Rock Creek Drainage	0												
Upper Tangle Lake	8	0.25	0.15	0	---	0	---	0.50	0.18	0	---	0.25	0.15
Mud Lake Head	1	0	---	0	---	0	---	0	---	0	---	1.00	0

^a Area = Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters.

^b p = mixing rate expressed as a proportion.

^c SE = standard error of the proportion.

^d NS = No sampling.

ended there while still occurring in the lower system. With summer recaptures showing these spawning populations do mix in the lower system, the likely explanation is that these recaptured fish were in transit to their feeding area.

Mixing of Fish Tagged in Summer:

Major summer tagging was conducted in four areas: lower system (Upper Delta River and Long Tangle Thoroughfare), Landmark Gap and Rock creeks, and the Tangle River. As found in the mixing of spring populations, the summer feeding populations of the lower system and Landmark Gap Creek were comprised of two or more spawning stocks (Table 15). The implied compositions, though, are not uniform. The spawning stocks of the upper system appeared to contribute the least to the populations. While no mixing of lower system spawning stocks was found in the upper system, the recapture of one Rock Creek fish in the spring at 18 Mile Creek indicates the mixing is more widespread.

Percentages of recaptured fish homing to summer feeding areas appeared to be less than percentages of recaptured fish homing to spawning areas. From 0 to 89% of all recaptures came from the area in which they were tagged (Table 16). The most straying occurred in populations from the Tangle River and 18 Mile Creek with 62 to 100% being recaptured elsewhere. The least straying occurred for lower system and Landmark Gap and Rock Creek fish (0 to 40%). As with straying of spawning stocks, these rates may be affected by timing and the definition of summer as well as sample sizes. It may also be affected by the maturity of the population tagged. Juveniles predominated in those populations that strayed the most (Appendix C2). Movements, and thus mixing, may be dependent upon the age of the fish. At present, there are too few recaptures for adequate analysis.

Fall mixing of summer populations showed the same general tendencies as for spawning populations: movements out of feeding areas (tributaries) into the lower and upper systems (Table 17).

Mixing of Fish Tagged in Fall:

Fish tagged in fall were of sizable numbers in only three locations: the Upper Delta River, Tangle River, and in the least extent, Upper Tangle Lake. Spring and summer mixing rates of these tagged fish followed the trends mentioned above with the exception of Tangle River (Tables 18 and 19). Mixing of fish tagged in fall from the Tangle River was more widespread than that of summer-tagged fish. This can be expected given the time of tagging and with fish presumably moving to overwintering areas.

Summary:

The above mixing rates should be considered preliminary. A host of variables have biased the reported rates. Unequal tagging effort among locations (especially that of anglers), unequal tagging effort across years as well as differing "time at large" for each tagging cohort, grouping juveniles with adults, and the condensing of a complex system into a few parts are some of the most problematic biases. Unfortunately, the database on recaptures is not

Table 15. Relative mixing rates of all Arctic grayling tagged in the summer and recaptured in the spring in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

Spring Recapture Area													
Summer Release Area ^a	Total Recaptures	Lower System		18 Mile Cr		Landmark		Tangle R.		Rock Ck.		Upper System	
		p ^b	SE ^c	p	SE	p	SE	p	SE	p	SE	p	SE
A; from test sampling:													
Lower System	21	0.57	0.11	0.33	0.10	NS ^d		NS		0	---	0.10	0.06
18 Mile Creek	2	0	---	1.00	0	NS		NS		0	---	0	---
Landmark Gap Drainage	8	0	---	0.88	0.12	NS		NS		0	---	0.12	0.12
Tangle River	7	0	---	0	0.10	NS		NS		0	---	1.00	0
Rock Creek Drainage	2	0	---	0.50	0.35	NS		NS		0	---	0.50	0.35
Upper System	1	0	---	0	---	NS		NS		0	---	1.00	0
B; from angler returns:													
Lower System	6	0	---	0.33	0.19	0	---	0.67	0.19	0	---	0	---
18 Mile Creek	0												
Landmark Gap Drainage	1	0	---	1.00	0	0	---	0	---	0	---	0	---
Tangle River	2	0	---	0	---	0	---	1.00	0	0	---	0	---
Rock Creek Drainage	0												
Upper System	0												

^a Area = Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters.

^b p = mixing rate expressed as a proportion.

^c SE = standard error of the proportion.

^d NS = No sampling.

Table 16. Relative mixing rates of all Arctic grayling tagged in the summer and recaptured in the summer at least one year later in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

Summer Recapture Area													
Summer Release Area ^a	Total Recaptures	Lower System		18 Mile Cr		Landmark		Tangle R.		Rock Ck.		Upper System	
		p ^b	SE ^c	p	SE	p	SE	p	SE	p	SE	p	SE
A; from test sampling:													
Lower System	53	0.81	0.05	0	---	0.15	0.05	0.04	0.03	0	---	0	---
18 Mile Creek	4	0	---	0	0	1.00	0	0	---	0	---	0	---
Landmark Gap Drainage	13	0	---	0	---	1.00	0	0	---	0	---	0	---
Tangle River	8	0.13	0.12	0	---	0	---	0.38	0.17	0.38	0.17	0.13	0.12
Rock Creek Drainage	10	0	---	0	---	0	---	0	---	1.00	0	0	---
Upper System	3	0.33	0.27	0	---	0	---	0	---	0.67	0.27	0	---
B; from angler reports:													
Lower System	18	0.89	0.07	0	---	0	---	0.06	0.05	0	---	0.06	0.05
18 Mile Creek	5	0.20	0.18	0.40	0.22	0	---	0.20	0.18	0	---	0.20	0.18
Landmark Gap Drainage	10	0.20	0.13	0.10	0.10	0.60	0.16	0	---	0	---	0.10	0.10
Tangle River	13	0.31	0.13	0	---	0	---	0.62	0.14	0.08	0.07	0	---
Rock Creek Drainage	9	0	---	0	---	0	---	0	---	0.89	0.11	0.11	0.11
Upper System	1	0	---	0	---	0	---	0	---	1.00	0	0	---

^a Area = Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters.

^b p = mixing rate expressed as a proportion.

^c SE = standard error of the proportion.

^d NS = No sampling.

Table 17. Relative mixing rates of all Arctic grayling tagged in the summer and recaptured in the fall in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

Fall Recapture Area													
Summer Release Area ^a	Total Recaptures	Lower System		18 Mile Cr		Landmark		Tangle R.		Rock Ck.		Upper System	
		p ^b	SE ^c	p	SE	p	SE	p	SE	p	SE	p	SE
A; from test sampling:													
Lower System	15	1.00	0	NS ^d		0	---	0	---	0	---	0	---
18 Mile Creek	0												
Landmark Gap Drainage	5	0.20	0.18	NS		0.80	0.18	0	---	0	---	0	---
Tangle River	7	0	---	NS		0	---	1.00	0	0	---	0	---
Rock Creek Drainage	14	0	---	NS		0	---	0	---	1.00	0	0	---
Upper System	0												
B; from angler reports:													
Lower System	8	0.50	0.18	0	---	0	---	0.38	0.17	0	---	0.12	0.12
18 Mile Creek	3	0	---	0	---	0	---	0.33	0.27	0	---	0.67	0.27
Landmark Gap Drainage	13	0.15	0.10	0	---	0.23	0.12	0.23	0.12	0.07	0.07	0.31	0.13
Tangle River	2	0.50	0.35	0	---	0	---	0.50	0.35	0	---	0	---
Rock Creek Drainage	8	0.12	0.12	0	---	0	---	0	---	0.25	0.15	0.63	0.17
Upper System	1	0	---	0	---	0	---	0	---	1.00	0	0	---

^a Area = Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters.

^b p = mixing rate expressed as a proportion.

^c SE = standard error of the proportion.

^d NS = No sampling.

Table 18. Relative mixing rates of all Arctic grayling tagged in the fall and recaptured in the spring in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

Fall Release Area ^a	Total Recaptures	Summer Recapture Area											
		Lower System		18 Mile Cr		Landmark		Tangle R.		Rock Ck.		Upper System	
		p ^b	SE ^c	p	SE	p	SE	p	SE	p	SE	p	SE
A; from test sampling:													
Lower System	9	0.56	0.17	0.33	0.16	NS ^d		NS		0	---	0.11	0.11
18 Mile Creek	NT ^e												
Landmark Gap Drainage	0												
Tangle River	17	0	---	0.29	0.11	NS		NS		0	---	0.71	0.11
Rock Creek Drainage	1	1.00	0	0	---	NS	---	NS	---	0	---	0	---
Upper System	6	0	---	0	---	NS	---	NS	---	0	---	1.00	0
B; from angler reports:													
Lower System	4	0.25	0.22	0	---	0	---	0.50	0.25	0	---	0.25	0.22
18 Mile Creek	NT												
Landmark Gap Drainage	0												
Tangle River	6	0	---	0	---	0	---	0.83	0.15	0	---	0.17	0.15
Rock Creek Drainage	1	0	---	0	---	0	---	0	---	0	---	1.00	0
Upper System	3	0	---	0	---	0	---	0.33	0.27	0	---	0.67	0.27

^a Area = Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters.

^b p = mixing rate expressed as a proportion.

^c SE = standard error of the proportion.

^d NS = No sampling.

^e NT = No tagging.

Table 19. Relative mixing rates of all Arctic grayling tagged in the fall and recaptured in the summer in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

Fall Release Area ^a	Total Recaptures	Summer Recapture Area											
		Lower System		18 Mile Cr		Landmark		Tangle R.		Rock Ck.		Upper System	
		p ^b	SE ^c	p	SE	p	SE	p	SE	p	SE	p	SE
A; from test sampling:													
Lower System	25	0.84	0.07	0	---	0.04	0.04	0.04	0.04	0	---	0.08	0.05
18 Mile Creek	NT ^e												
Landmark Gap Drainage	0												
Tangle River	24	0.25	0.09	0.21	0.08	0.25	0.09	0.25	0.09	0.04	0.04	0	---
Rock Creek Drainage	8	0	---	0	---	0	---	0	---	1.00	0	0	---
Upper System	1	0	---	0	---	0	---	0	---	0	---	1.00	0
B; from angler reports:													
Lower System	2	1.00	0	0	---	0	---	0	---	0	---	0	---
18 Mile Creek	NT												
Landmark Gap Drainage	0												
Tangle River	24	0.17	0.08	0	---	0.04	0.04	0.71	0.09	0	---	0.08	0.06
Rock Creek Drainage	3	0	---	0	---	0	---	0	---	0.67	0.27	0.33	0.27
Upper System	4	0	---	0	---	0	---	0.50	0.25	0	---	0.50	0.25

^a Area = Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters.

^b p = mixing rate expressed as a proportion.

^c SE = standard error of the proportion.

^d NS = No sampling.

^e NT = No tagging.

yet large enough to address them all. The most opportune strategy would be to direct sampling effort at spawning locations (for stock assessment) and to the recovery of tags from the fishery (for mixing rates). In addition, efforts towards partitioning of the fishery into specific locations would afford accurate estimates of not only exploitation but real world estimates of mixing. The resulting data should afford managers with a firm basis and rationale towards maintaining a popular and unique fishery.

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LITERATURE CITED

- Armstrong R. H. 1982. Arctic grayling studies in Alaska. Alaska Cooperative Fisheries Research Unit and the Alaska Department of Fish and Game, Alaska. 1,593 pp.
- Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. *Biometrika* 38: 293-306.
- _____. 1952. Improvements in the interpretation of recapture data. *Journal of Animal Ecology* 21 120-127.
- Baker, T. T. 1988. Creel censuses in interior Alaska in 1987. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 64, Anchorage, Alaska. 123 pp.
- _____. 1989. Stock assessment of Arctic grayling in the Tangle Lakes and River system. Alaska Department of Fish and Game, Fishery Data Series No. 92, Juneau, Alaska. 54 pp.
- Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. *University of California Publications in Statistics* 1: 131-160.

LITERATURE CITED (Continued)

- Clark, R. A. and, W. P. Ridder. 1987. Abundance and length composition of selected grayling stocks in the Tanana drainage during 1986. Alaska Department of Fish and Game, Fishery Data Series No. 26, Juneau, Alaska. 55 pp.
- _____. 1988. Stock assessment of Arctic grayling in the Tanana drainage. Alaska Department of Fish and Game, Fishery Data Series No. 54, Juneau, Alaska. 79 pp.
- Finney, D. J. 1971. Statistical methods in biological assay, second edition. Charles Griffin & Company, Ltd. London. 668 pp.
- Gabelhouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.
- Goodman, L. A. 1960. On the exact variance of products. Journal of American Statistical Association. Volume 55:708-713.
- Heckart, L. 1965. Inventory and cataloging of the sport fish and sport fish waters in the interior of Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1964-1965, Project F-5-R-6, 6 (15-A):291-305.
- Holmes, R. A., W. P. Ridder, and R. A. Clark. 1986. Distribution, abundance, and natural history of the Arctic grayling in the Tanana drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-1986, Project F-10-1, 27 (G-8-1). 68 pp.
- Mills, M. J. 1979. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20 (SW-I-A). 112 pp.
- _____. 1980. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-I-A). 65 pp.
- _____. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A). 77 pp.
- _____. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A). 107 pp.

LITERATURE CITED (Continued)

- _____. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23 (SW-I-A). 115 pp.
- _____. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (SW-I-A). 119 pp.
- _____. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (SW-I-A). 123 pp.
- _____. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26 (SW-I-A). 137 pp.
- _____. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27 (RT-2). 137 pp.
- _____. 1987. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau, Alaska. 140 pp.
- _____. 1988. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau, Alaska. 140 pp.
- _____. 1989. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau, Alaska. 142 pp.
- _____. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage, Alaska. 152 pp.
- Peckham, R. D. 1974. Evaluation of interior Alaska waters and sport fish with emphasis on stocked lakes. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1973-1974, Project F-9-6, 15 (G-III-E):1-34.
- _____. 1977. Evaluation of interior Alaska waters and sport fish with emphasis on stocked lakes - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1976-1977, Project F-9-9, 18 (G-III-E):40-99.

LITERATURE CITED (Continued)

- Ridder, W. P. 1983. A study of a typical spring-fed stream of interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (G-III-G). 54 pp.
- _____. 1989a. Age, length, sex, and abundance of Arctic grayling in Mineral Lake Outlet, 1969 through 1988. Alaska Department of Fish and Game, Fishery Data Series No. 87, Juneau, Alaska. 36 pp.
- _____. 1989b. Age, length, sex, and abundance of Arctic grayling in the Goodpaster River, 1956 through 1988. Alaska Department of Fish and Game, Fishery Data Series No. 94, Anchorage, Alaska. 49 pp.
- _____. 1990. Stock assessment of Arctic grayling in the Tangle lakes and river system, 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-15, Anchorage, Alaska. 55 pp.
- _____. 1991. *In press*. Summary of recaptures of Arctic grayling tagged in the middle Tanana River drainage, 1977 through 1990. Alaska Department of Fish and Game, Fishery Data Series, Anchorage, Alaska.
- Roguski, E. A. 1967. Investigations of the Tanana River and Tangle Lake fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Progress Report, 1966-1967, Project F-5-R-8, 8 (16-B):247-255.
- Roguski, E. A. and, S. L. Tack. 1970. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1969-1970, Project F-9-2, 11 (16-B):303-319.
- Roguski, E. A. and, P. C. Winslow. 1969. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1968-1969, Project F-9-1, 10 (16-B):19 pp.
- Schallock, E. D. 1966. Investigations of the Tanana River and Tangle Lakes fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1965-1966, Project F-4-R-7, 7 (16-B):231-247.
- Scott, W. B. and, E. J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada, Ottawa. 966 pp.
- Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Co., Ltd. London, VK. 654 pp.

LITERATURE CITED (Continued)

- Tack, S. L. 1980. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1971-1980. Project F-9-12, 21 (R-I). 35 pp.
- Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41 (1):42-46.
- Warner, G. 1955a. Dynamics of fish populations in waters of interior Alaska. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report, Project F-1-R-4, Work Plan C, Job No.3, 4 (3,4):7 pp.
- _____. 1955b. Survey of Tangle Lakes. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report, Project F-1-R-4, Work Plan C, Job No. 4, 4 (1):8 pp.
- _____. 1956. Catch distribution, age and size composition of sport fish in the Fairbanks area. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report, Project F-1-R-5, Work Plan A, Job No.3, 5:8 pp.
- _____. 1957. Catch distribution, age and size composition of sport fish in the Fairbanks area. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report, Project F-1-R-6, Work Plan A, Job No.3, 6 (4):8 pp.
- _____. 1958. Catch distribution, age and size composition of sport fish in the Fairbanks area. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report, Project F-1-R-7, Work Plan A, Job No.3, 7 (2):10 pp.
- _____. 1959. Catch distribution, age and size composition of sport fish in the Fairbanks area. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report, Project F-1-R-8, Work Plan A, Job No.3c, 8 (3):7 pp.
- Wojcik, F. 1953a. Reconnaissance surveys of sport fishing pressure, Fairbanks area. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-3, Work Plan 1, Job 3 (3):5 pp.
- _____. 1953b. Movements and migration habits of grayling in interior Alaska. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-3, Work Plan 5, Job 4, 3 (2):7 pp.

LITERATURE CITED (Continued)

- _____. 1953c. Food habits of grayling in interior Alaska. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-3, Work Plan 5, Job 3 (3):5 pp.
- _____. 1953d. Survey of Tangle Lakes, Fairbanks area. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-3, Work Plan 3, Job 2, 3 (4):13 pp.
- _____. 1953e. Growth rates of grayling in interior waters. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-3, Work Plan 5, Job 1, 3 (4):10 pp.
- _____. 1953f. Biological survey of the Chatanika River. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-4, Work Plan C, Job 5, 4 (2):4 pp.
- _____. 1953g. Movements and migration habits of grayling in interior Alaska. U. S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-4, Work Plan E, Job 2, 4 (2):1 pp.

APPENDIX A
Harvest and Effort Statistics

Appendix A1. Estimated recreational harvest of Arctic grayling and total angling effort on the Tangle Lakes system, 1978 through 1989^a.

Year	Effort ^b		Harvest	CPUE ^d
	Anglers	Angler-days		
1978	NA ^c	7,711	5,786	0.75
1979	NA	5,864	3,466	0.59
1980	NA	8,198	5,522	0.67
1981	NA	5,530	6,858	1.24
1982	NA	9,502	9,590	1.01
1983	NA	5,513	7,794	1.41
1984	1,707	3,954	4,829	1.22
1985	4,112	6,225	5,827	0.93
1986	3,742	5,545	5,038	0.91
1987	2,460	2,530	2,467	0.98
1988	2,413	3,456	4,675	1.35
1989	3,658	3,991	3,136	0.79
Averages	3,015	5,668	5,416	0.96

^a Data sources: Mills (1979 - 1990).

^b Effort estimates include effort expended for all species.

^c NA = data not available.

^d CPUE = the number of Arctic grayling harvested per angler-day.

APPENDIX B
Detection of Bias

Appendix B1. Methodologies for alleviating bias due to gear selectivity by means of statistical inference.

Result of first K-S test^a

Result of second K-S test^b

Case I^c

Fail to reject H_0

Fail to reject H_0

Inferred cause: There is no size-selectivity during either sampling event.

Case II^d

Fail to reject H_0

Reject H_0

Inferred cause: There is no size-selectivity during the second sampling event, but there is during the first sampling event

Case III^e

Reject H_0

Fail to reject H_0

Inferred cause: There is size-selectivity during both sampling events.

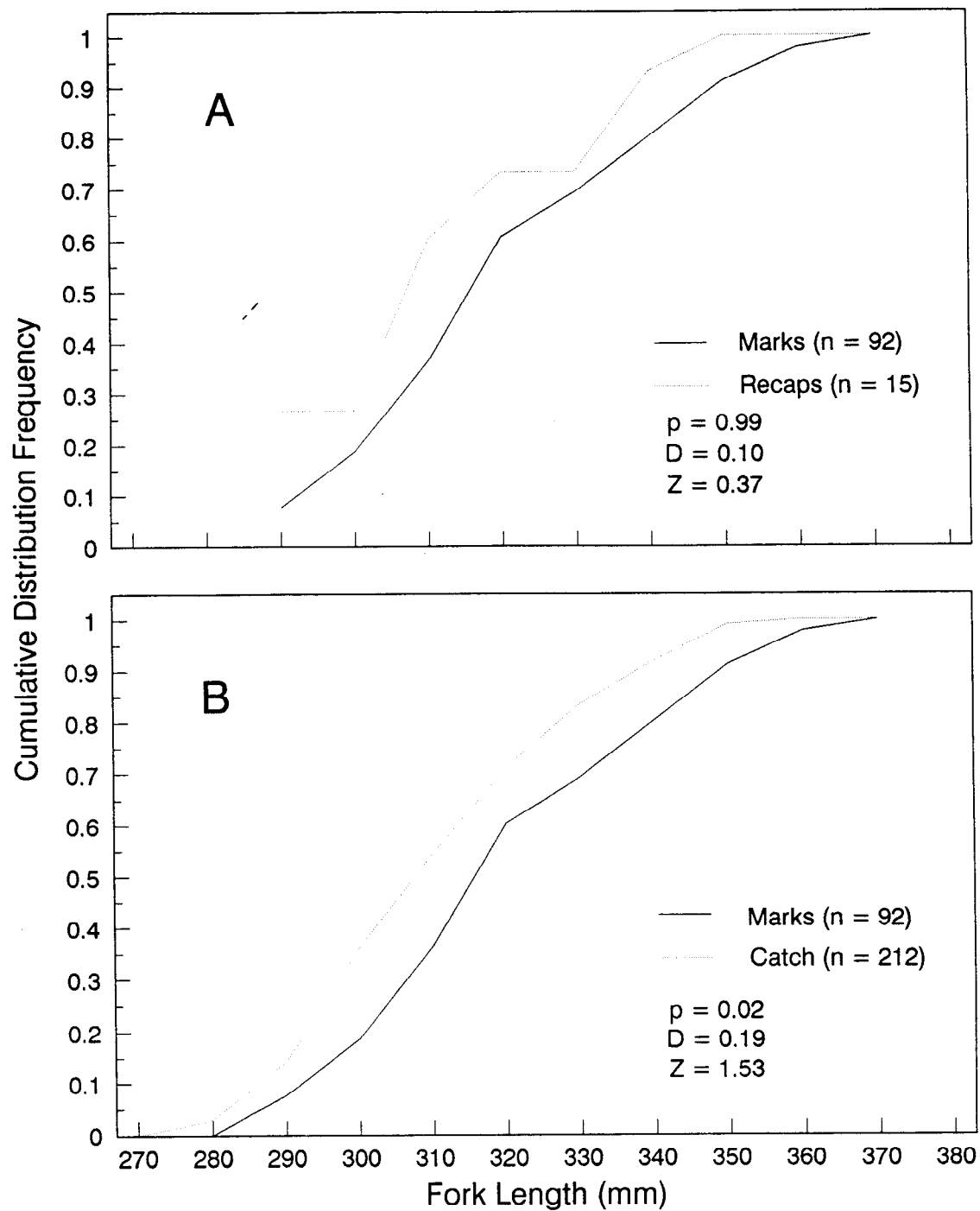
Case IV^f

Reject H_0

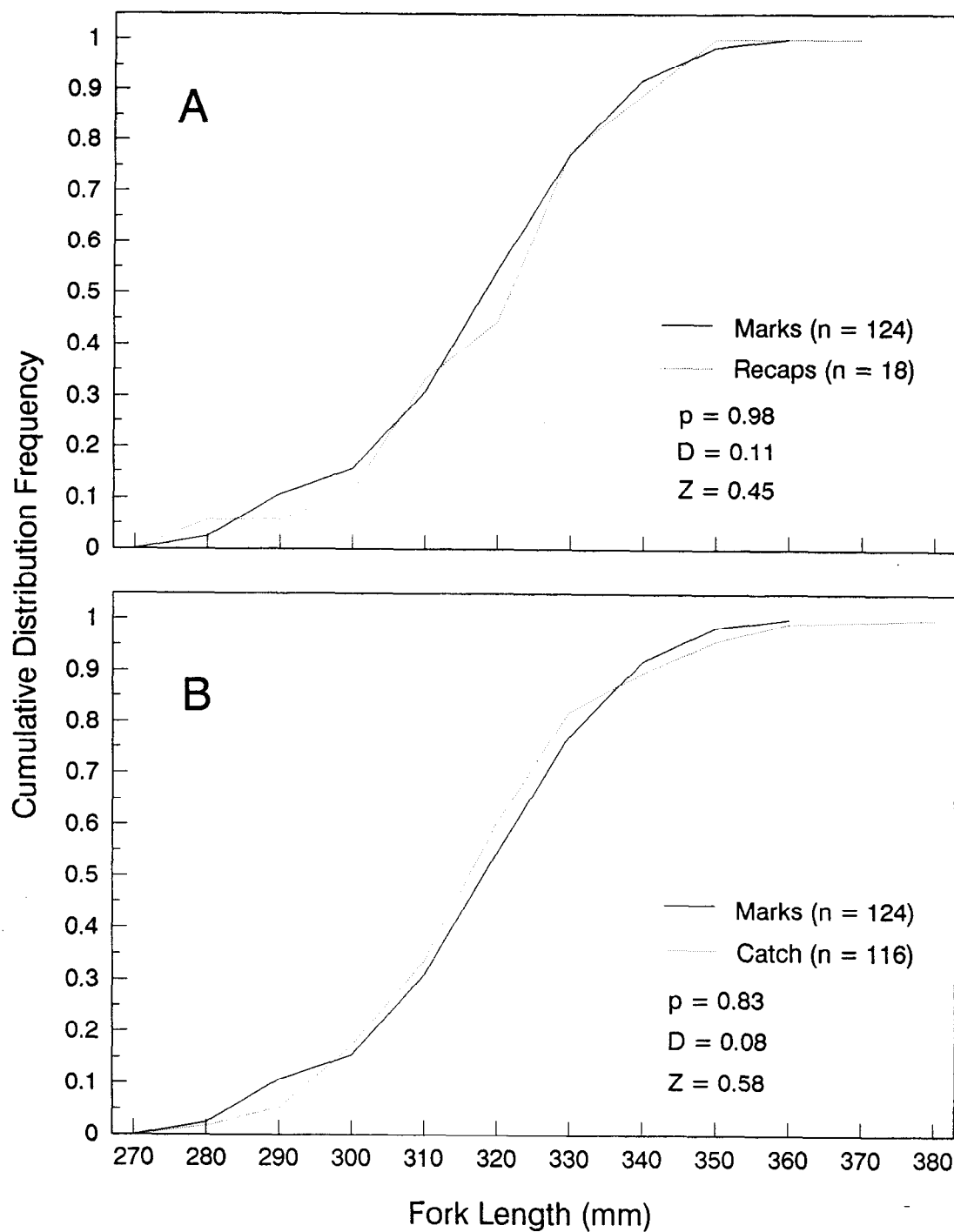
Reject H_0

Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

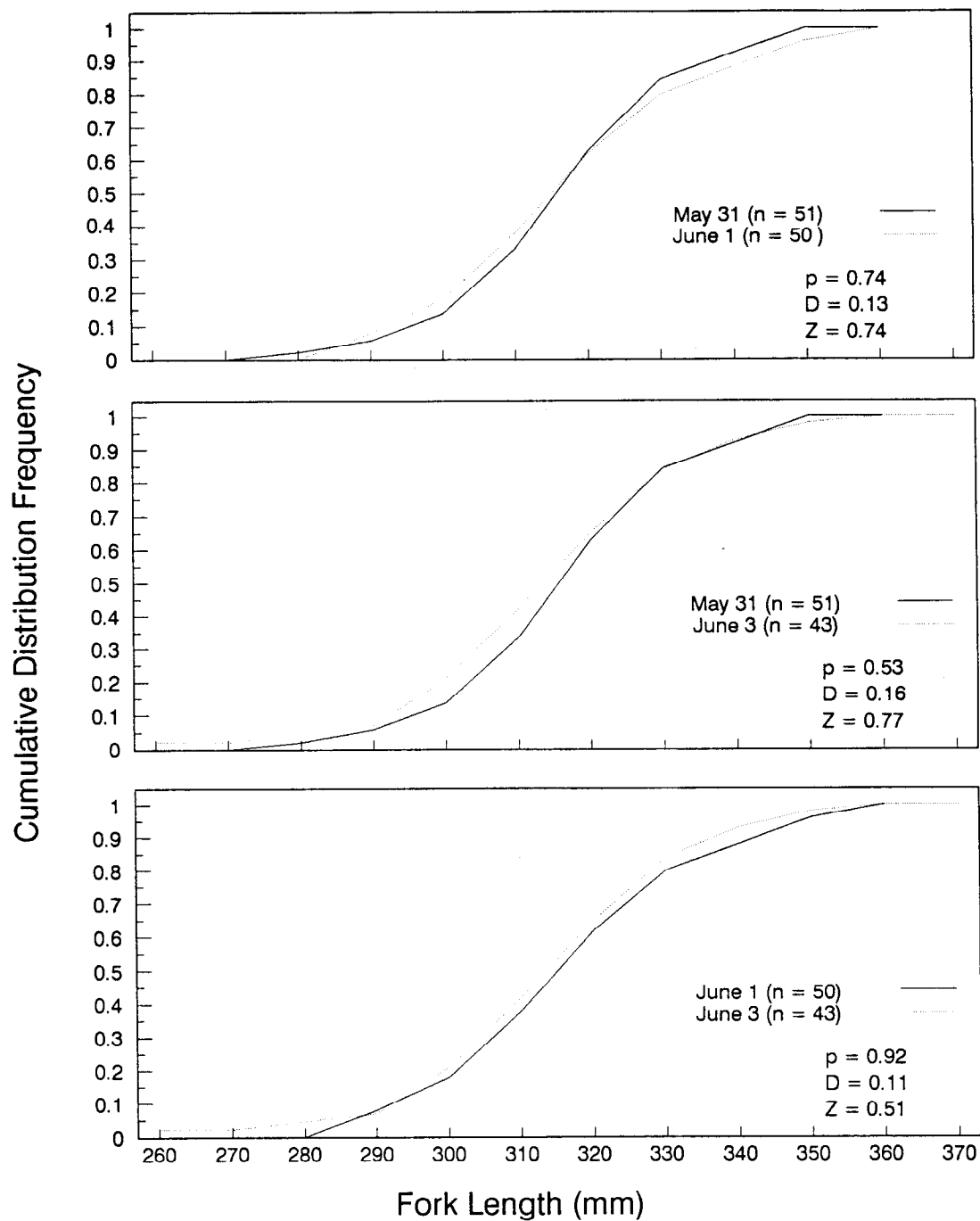
-
- ^a The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.
 - ^b The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.
 - ^c Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.
 - ^d Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.
 - ^e Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.
 - ^f Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.
If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.
If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.



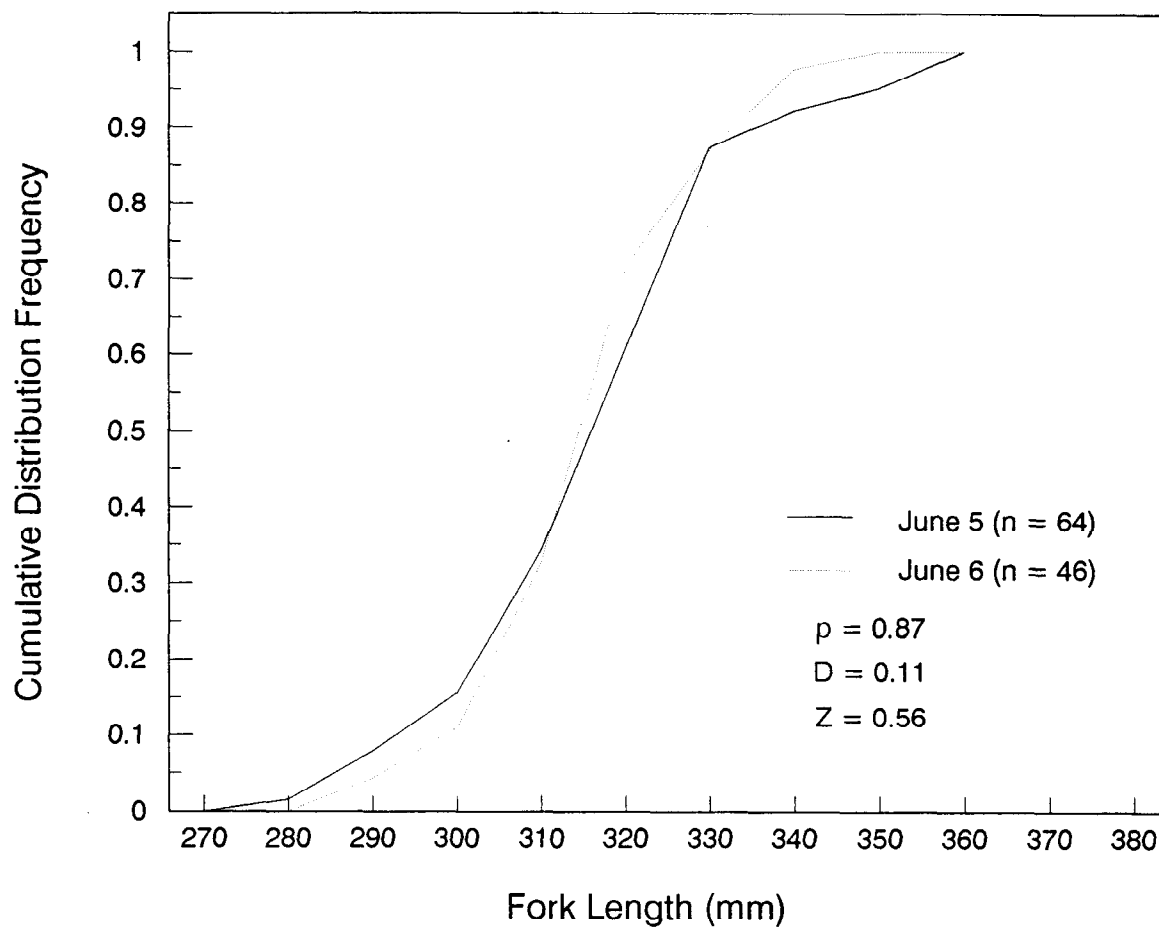
Appendix B2. Cumulative distribution functions of lengths of mature Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for the Tundra Pond of 18 Mile Creek, 22 through 28 May 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.



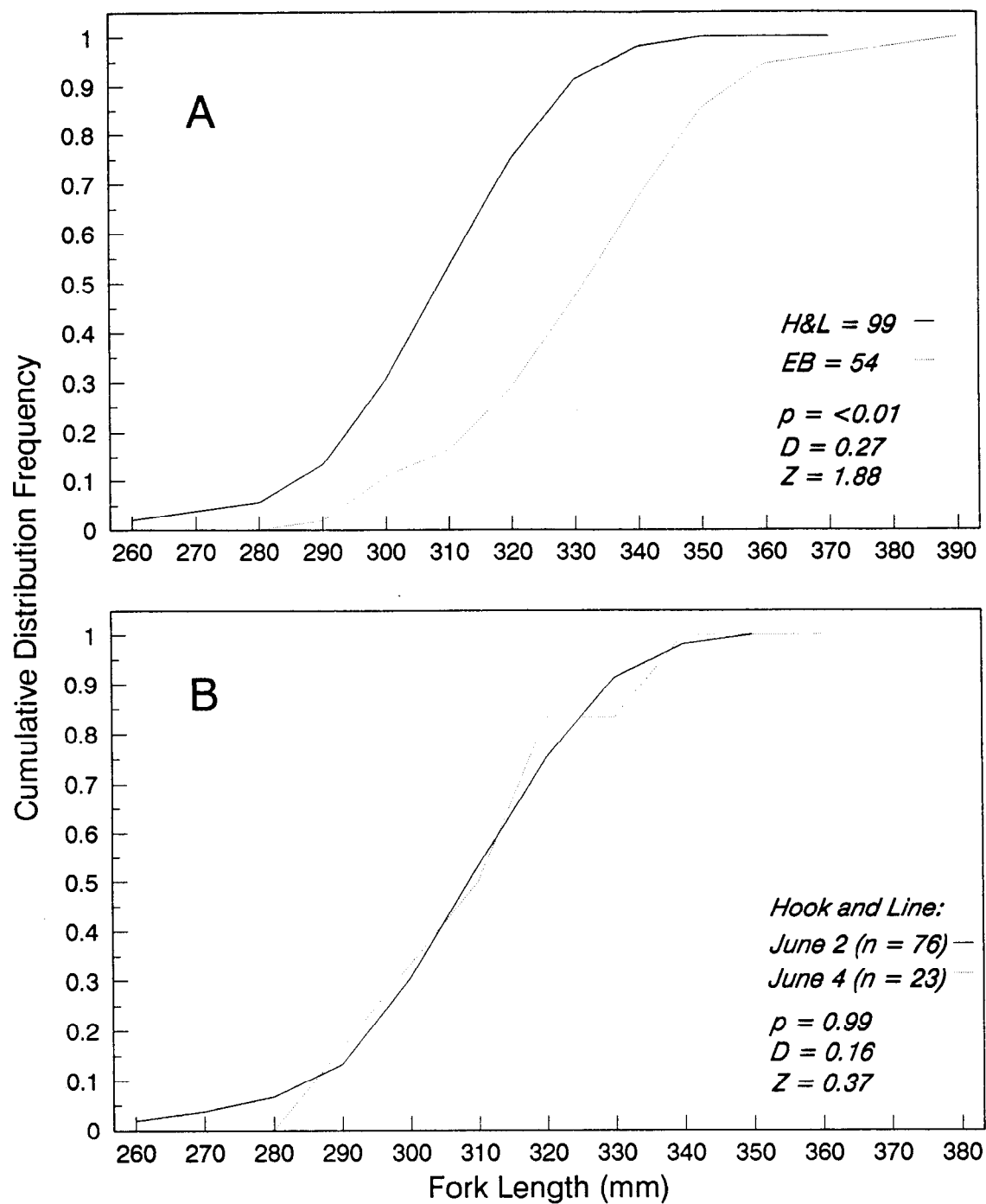
Appendix B3. Cumulative distribution functions of lengths of mature Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for the thoroughfare in mid-Long Tangle Lake, 4 through 6 June 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.



Appendix B4. Three combinations of cumulative distribution functions of lengths of mature Arctic grayling captured during three events at the head of Mud Lake, 31 May through 3 June 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.



Appendix B5. Cumulative distribution functions of lengths of mature Arctic grayling captured during two events at the outlet to Lower Tangle Lake, 5 and 6 June 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.



Appendix B6. Cumulative distribution functions of lengths of mature Arctic grayling captured by hook and line versus those captured by electrofishing (A) and between hook and line sample events (B) at the head of Long Tangle Lake, 2 through 6 June 1990. Statistics are from the Kolmogorov-Smirnov two-sample test.

APPENDIX C

Unadjusted Age and Size Compositions

Appendix C1. Unadjusted age composition estimates by gear type and location for all Arctic grayling sampled from six locations in the Tangle Lakes system, 22 May through 7 June 1990.

Age Class	Lower Tangle LK 5 June - 6 June Electrofishing			Long Tangle Lk Thoro. 4 June - 6 June Electrofishing			Long Tangle Lk Head 2 June - 6 June Electrofishing			Long Tangle Lk Head 2 June - 6 June Hook and Line			Mud Lake Head 31 May - 3 June Hook and Line			Mud Lake Head 3 June Seine		
	n ^b	%	SE ^c	n	%	SE	n	%	SE	n	%	SE	n	%	SE	n	%	SE
1	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	2	2.8	1.9
2	0	---	---	1	0.3	0.3	0	---	---	0	---	---	8	4.0	1.4	36	50.0	5.9
3	0	---	---	24	7.8	1.5	2	3.2	2.2	5	4.4	1.9	28	14.0	2.5	16	22.2	4.9
4	9	8.2	2.6	27	8.8	1.6	8	12.9	4.3	17	15.0	3.4	23	11.5	2.3	4	5.6	2.7
5	2	1.8	1.3	30	9.8	1.7	9	14.5	4.5	18	15.9	3.4	26	13.0	2.4	0	---	---
6	55	50.0	4.7	114	37.3	2.8	25	40.3	6.2	57	50.4	4.7	82	41.0	3.5	8	11.1	3.7
7	41	37.3	4.6	98	32.0	2.7	14	22.6	5.3	16	14.2	3.3	29	14.5	2.5	5	6.9	3.0
8	3	2.7	1.6	11	3.6	1.1	2	3.2	2.2	0	---	---	4	2.0	1.0	1	1.4	1.4
9	0	---	---	1	0.3	0.3	2	3.2	2.2	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	110	100.0		306	100.0		62	100.0		113	100.0		200	100.0		72	100.0	

-continued-

Appendix C1. (Page 2 of 2).

Age Class	Upper Rock Creek 6 June - 7 June Hook and Line			18 Mile Creek 22 May - 6 June Hook and Line		
	n	%	SE	n	%	SE
1	0	---	---	0	---	---
2	0	---	---	0	---	---
3	0	---	---	0	---	---
4	0	---	---	2	0.7	0.5
5	0	---	---	28	9.2	1.7
6	4	8.7	4.2	140	46.2	2.9
7	8	17.4	5.6	104	34.3	2.7
8	22	47.8	7.4	26	8.6	1.6
9	11	23.9	6.3	3	1.0	0.6
10	1	2.2	2.2	0	---	---
Total	46	100.0		303	100.0	

^a EB = electrofishing boat; HL = hook and line.

^b n = sample size.

^c SE = standard error of the percentage.

Appendix C2. Unadjusted age composition estimates by area for all Arctic grayling sampled^a from four locations in the Tangle Lakes system, July and August 1990.

Age Class	Rock Creek 4, 17 - 19 July			Landmark Gap Creek 10 - 13 July			Landmark Gap Creek 21 - 22 August			Long Tangle Lake Thoroughfare 11 & 20 July			Upper Delta River 3, 10, 12 July		
	n ^b	%	SE ^c	n	%	SE	n	%	SE	n	%	SE	n	%	SE
1	14	4.7	1.2	11	3.6	1.1	9	3.9	1.3	0	---	---	0	---	---
2	93	31.5	2.7	79	25.6	2.5	106	46.5	3.3	10	7.0	2.1	26	8.7	1.6
3	102	34.6	2.8	104	33.8	2.7	92	40.4	3.2	33	23.8	3.5	71	23.7	2.5
4	46	15.6	2.1	37	12.0	1.9	17	7.5	1.7	25	17.6	3.2	38	12.7	1.9
5	18	6.1	1.4	37	12.0	1.9	3	1.3	0.8	39	27.5	3.7	53	17.7	2.2
6	12	4.1	1.2	31	10.1	1.7	1	0.4	0.4	32	22.5	3.5	92	30.8	2.7
7	9	3.1	1.0	9	2.9	1.0	0	---	---	3	2.1	1.2	16	5.4	1.3
8	1	0.3	0.3	0	---	---	0	---	---	0	---	---	3	1.0	0.6
9	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	295	100.0		308	100.0		228	100.0		142	100.0		299	100.0	

^a Gear type was hook and line.

^b n = sample size.

^c SE = standard error of the percentage.

Appendix C3. Unadjusted mean fork length at age for Arctic grayling sampled from six locations in the Tangle Lakes system, 22 May through 7 June 1990.

Age Class	Lower Tangle LK 5 June - 6 June			Long Tangle Lk Thoro. 4 June - 6 June			Long Tangle Lk Head 2 June - 6 June			18 Mile Creek 22 May - 6 June			Mud Lake Head 31 May - 3 June			Upper Rock Creek 6 June - 7 June		
	n ^a	FL ^b	SD ^c	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	0	---	---	0	---	---	2	137	3	0	---	---
2	0	---	---	1	155	0	0	---	---	0	---	---	44	179	16	0	---	---
3	0	---	---	24	206	8	7	225	9	0	---	---	44	213	24	0	---	---
4	9	243	14	27	242	11	25	249	13	2	285	7	27	261	18	0	---	---
5	2	266	24	30	277	17	27	282	21	28	290	15	26	305	21	0	---	---
6	55	319	12	114	316	17	82	316	17	140	308	19	90	321	19	4	347	33
7	41	329	14	98	330	17	30	331	15	104	326	16	34	336	13	8	370	23
8	3	344	15	11	345	10	2	343	2	26	346	17	5	350	14	22	372	16
9	0	---	---	1	362	0	2	388	15	3	335	18	0	---	---	11	376	20
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	1	417	0
Total	110	316	27	306	302	42	175	303	37	303	315	23	272	264	68	46	372	22

^a n = sample size.

^b FL = mean fork length at age.

^c SD = sample standard deviation of FL.

Appendix C4. Unadjusted mean fork length at age for Arctic grayling sampled^a from four locations in the Tangle Lakes system, July and August 1990.

Age Class	Rock Creek 4,17-19 July			Landmark Gap Creek 10 - 13 July			Landmark Gap Creek 21 - 22 August			Long Tangle Lake Thoroughfare 11 & 20 July			Upper Delta River 19 - 20 July		
	n ^b	FL ^c	SD ^d	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	14	131	11	11	141	10	9	142	13	0	---	---	0	---	---
2	93	177	15	79	180	19	106	187	20	10	181	7	26	178	9
3	102	213	24	104	213	20	92	218	15	33	220	18	71	219	22
4	46	262	18	37	260	18	17	255	22	24	272	19	38	253	20
5	18	291	19	37	290	21	3	270	19	39	305	20	53	299	18
6	12	329	12	31	303	22	1	297	19	32	316	21	92	322	18
7	9	334	21	9	319	28	0	---	---	3	344	10	16	350	17
8	1	380	0	0	---	---	0	---	---	0	---	---	3	371	6
9	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	295	220	53	308	230	52	228	196	34	142	274	49	299	277	57

^a Gear type was hook and line except for Glacier Lake which was gill net.

^b n = sample size.

^c FL = mean fork length at age.

^d SD = sample standard deviation of FL.

Appendix C5. Unadjusted mean fork length at age for mature male Arctic grayling sampled from six locations in the Tangle Lakes system, 22 May through 7 June 1990.

Age Class	Lower Tangle LK 5 June - 6 June			Long Tangle Lk Thoro. 4 June - 6 June			Long Tangle Lk Head 2 June - 6 June			18 Mile Creek 22 May - 6 June			Mud Lake Head 31 May - 3 June			Upper Rock Creek 6 June - 7 June		
	n ^a	FL ^b	SD ^c	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
2	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
3	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
4	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
5	1	290	24	3	306	8	4	304	13	8	304	9	4	329	16	0	---	---
6	46	320	12	77	320	14	46	321	16	59	317	17	34	331	15	2	379	11
7	37	331	14	80	332	16	23	336	11	45	333	14	13	337	15	3	387	25
8	3	344	15	8	349	9	2	343	2	17	348	16	4	352	16	17	376	16
9	0	---	---	1	362	0	2	388	15	2	348	4	0	---	---	10	378	19
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	1	417	0
Total	87	325	15	169	327	17	77	321	19	131	326	20	55	334	16	33	379	19

^a n = sample size.

^b FL = mean fork length at age.

^c SD = sample standard deviation of FL.

Appendix C6. Unadjusted mean fork length at age for mature female Arctic grayling sampled from six locations in the Tangle Lakes system, 22 May through 7 June 1990.

Age Class	Lower Tangle LK 5 June - 6 June			Long Tangle Lk Thoro. 4 June - 6 June			Long Tangle Lk Head 2 June - 6 June			18 Mile Creek 22 May - 6 June			Mud Lake Head 31 May - 3 June			Upper Rock Creek 6 June - 7 June		
	n ^a	FL ^b	SD ^c	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
2	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
3	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
4	0	---	---	0	---	---	1	277	0	0	---	---	1	264	0	0	---	---
5	0	---	---	1	292	0	7	295	19	9	296	8	11	313	13	0	---	---
6	7	316	7	19	318	22	29	312	12	49	308	15	47	318	13	2	315	5
7	3	312	13	11	327	17	4	318	18	54	322	14	21	335	11	5	360	15
8	0	---	---	3	337	6	0	---	---	8	339	17	1	344	0	5	362	12
9	0	---	---	0	---	---	0	---	---	1	310	0	0	---	---	1	350	0
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	10	315	9	34	321	20	41	311	15	121	316	18	81	320	17	13	375	30

^a n = sample size.

^b FL = mean fork length at age.

^c SD = sample standard deviation of FL.

Appendix C7. Summary of unadjusted Relative Stock Density (RSD) indices for Arctic grayling sampled from the Tangle Lakes system by area, date, and gear type during 1990.

		RSD Category ^a				
		Stock	Quality	Preferred	Memorable	Trophy
<u>Lower Tangle Lake Outlet:</u>						
5 June - 6 June						
Electrofishing	n ^b	10	104	14	0	0
	% ^c	7.8	81.3	10.9	---	---
	S ^d	2.4	3.4	2.8	---	---
<u>Long Tangle Lake Thoroughfare:</u>						
2 June - 6 June						
Electrofishing	n	70	228	46	0	0
	%	20.3	66.3	13.4	---	---
	SE	2.2	2.7	1.8	---	---
<u>Long Tangle Lake Head:</u>						
2 June - 6 June						
Electrofishing	n	15	41	17	0	0
	%	20.5	56.2	23.3	---	---
	SE	4.7	5.8	4.9	---	---
<u>Long Tangle Lake Head:</u>						
2 June - 6 June						
H&L	n	31	101	7	0	0
	%	22.3	72.7	5.0	---	---
	SE	3.5	3.8	1.9	---	---
<u>18 Mile Creek:</u>						
31 May - 4 June						
H&L ^e	n	10	279	61	0	0
	%	2.9	79.7	17.4	---	---
	SE	0.9	2.1	2.0	---	---
<u>Upper Rock Creek</u>						
6 June - 7 June						
H&L	n	0	3	47	0	0
	%	---	6.0	94.0	---	---
	SE	---	3.3	3.3	---	---

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		RSD Category				
		Stock	Quality	Preferred	Memorable	Trophy
<u>Mud Lake Head:</u>						
31 May - 3 June						
H&L	n	52	136	25	0	0
	%	24.4	63.8	11.7	---	---
	SE	2.9	3.3	2.2	---	---
<u>Mud Lake Head:</u>						
3 June						
Seine	n	75	8	7	0	0
	%	83.3	8.9	7.8	---	---
	SE	3.9	3.0	2.8	---	---
<u>Upper Delta River:</u>						
3 July - 12 July						
H&L	n	136	144	39	0	0
	%	42.6	45.1	12.2	---	---
	SE	2.8	2.8	1.8	---	---
<u>Long Tangle Lake Thoroughfare:</u>						
11 July, 20 July						
H&L	n	60	82	8	0	0
	%	40.0	54.7	5.3	---	---
	SE	4.0	4.1	1.8	---	---
<u>Landmark Gap Creek:</u>						
10 July - 13 July						
H&L	n	222	86	4	0	0
	%	71.2	27.6	1.3	---	---
	SE	2.6	2.5	0.6	---	---
<u>Landmark Gap Creek:</u>						
21 - 22 August						
H&L	n	272	8	0	0	0
	%	97.1	2.9	---	---	---
	SE	1.0	1.0	---	---	---

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		RSD Category				
		Stock	Quality	Preferred	Memorable	Trophy
<u>Rock Creek:</u>						
4 July - 17 - 19 July						
H&L	n	234	54	6	0	0
	%	79.6	18.4	2.0	---	---
	SE	2.4	2.3	0.8	---	---
<u>Rock Creek:</u>						
22 August						
H&L	n	25	12	3	0	0
	%	62.5	30.0	7.5	---	---
	SE	7.7	7.2	4.2	---	---
<u>Glacier Lake:</u>						
19 - 20 August						
Gill net	n	41	35	27	0	0
	%	39.8	34.0	26.2	---	---
	SE	4.8	4.7	4.3	---	---

^a Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):

Stock - 150 mm

Quality - 270 mm

Preferred - 340 mm

Memorable - 450 mm

Trophy - 560 mm

^b n = sample size in RSD category.

^c % = percent of RSD category in total sample.

^d SE = standard error of percentage.

^e H&L = hook and line.

APPENDIX D

Historical Catch Summaries

Appendix D1. Summary of all Arctic grayling sampled in the Tangle Lakes system from 1986 through 1990. Samples are partitioned by year, location, maturity, and season.

Locations				1986			1987			1988			1989			1990			Totals		
Site	Codes	Area	Season	All	>199mm	Adult ^a	All	>199mm	Adult	All	>199mm	Adult	All	>199mm	Adult	All	>199mm	Adult	All	>199mm	Adult
Upper Delta River	075-	1	spring	0			0			0			0			128	128	114	128	128	114
through	175		summer	0			0			620	579	324	394	344	212	321	281	161	1,335	1,204	697
Lower Tangle Lake			fall	0			0			446	426	355	0			0			446	426	355
Long Tangle Lake	200-	1	spring	0			0			0			6	6	6	352	345	259	358	351	265
	250		summer	0			0			257	20	3	294	208	87	151	134	72	702	362	162
			fall	0			0			0			0			0			0		
Shallow Tangle Lake	251-	1	spring	0			0			0			247	247	224	211	210	153	458	457	377
and Thoroughfare	325		summer	0			86	74	2	173	79	14	0			0			259	179	38
			fall	0			0			0			26	26	22	0			26	26	22
Clear/18 Mile Creek	380-	2	spring	0			0			0			266	265	200	352	352	317	618	617	517
	392		summer	0			2	2	1	324	81	9	15	14	2	0			341	97	12
			fall	0			0			0			0			0			0		
Landmark Gap	360-	3	spring	0			0			0			0			0			0		
Drainage	375		summer	0			0			331	276	112	333	280	130	323	217	58	987	773	300
			fall	0			0			0			26	7	1	307	147	3	333	154	4
Round Tangle Lake	350,	1	spring	0			0			0			3	3	1	0			3	3	1
and Thoroughfare	400-		summer	0			21	21	14	742	149	56	44	38	15	0			807	208	85
	490		fall	82	25	2	10	10	3	0			0			0			92	35	5
Tangle River	500-	4	spring	0			0			0			0			0			0		
	502		summer	0			439	166	7	339	37	9	4	4	2	0			782	207	18
			fall	351	175	6	744	292	15	774	246	12	307	127	17	0			2,176	840	50

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Appendix D1. (Page 2 of 2).

Locations				1986			1987			1988			1989			1990			Totals		
Site	Codes	Area	Season	All >199mm Adult			All >199mm Adult			All >199mm Adult			All >199mm Adult			All >199mm Adult			All >199mm Adult		
Upper Tangle Lake	600-	6	spring	0			0			610	379	179	308	178	61	14	14	3	932	571	243
	605,		summer	0			24	16	3	96	96	73	0		0				120	112	76
	690		fall	134	11	2	0			59	59	47	115	114	103	0			308	184	152
Rock Creek	610-	5	spring	0			0			0			0			51	51	51	51	51	51
	680		summer	0			0			43	32	12	226	188	63	309	172	39	578	392	114
			fall	0			0			289	226	80	26	3	0	43	27	13	358	256	93
Glacier Lake	488	5	spring	0			0			0			0			0			0		
			summer	0			0			0			122	122	96	0			122	122	96
			fall	0			0			0			15	11	0	103	103	48	118	114	48
Upper Tangle River	700-	6	spring	0			0			0			131	96	13	75	22	5	206	118	18
	790		summer	0			0			0			48	6	0	0			48	6	0
			fall	0			0			417	189	8	3	0	0	0			420	189	8
Mud Lake to Headwaters	900-	6	spring	0			0			0			39	39	39	344	255	244	383	294	283
	905		summer	0			0			0			0			0			0		
			fall	0			0			0			0			0			0		
Harvest Samples	Misc.	All		243	232	93	239	230	96	41	41	29	167	166	92	0			690	669	310
Sub totals:				0			0			610	379	179	1,000	834	544	1,527	1,377	1,146	3,137	2,590	1,869
				243	232	93	811	509	123	2,966	1,390	641	1,647	1,370	699	1,104	804	330	6,771	4,331	1,908
				567	211	10	754	302	18	1,985	1,146	502	518	288	143	453	277	64	4,277	2,224	737
Totals				810	443	103	1,565	811	141	5,561	2,915	1,322	3,165	2,492	1,386	3,084	2,458	1,540			

^a Adult portion of catch determined by LM₅₀ of 289 mm FL.

Appendix D2. Summary of all Arctic grayling marked and released in the Tangle Lakes system from 1986 through 1990. Samples are partitioned by year, location, maturity, and season.

Locations				1986		1987		1988		1989		1990		Totals	
Site	Codes	Area	Season	All	Juv Adult ^a	All	Juv Adult	All	Juv Adult	All	Juv Adult	All	Juv Adult	All	Juv Adult
Upper Delta River through Lower Tangle Lake	075-	1	spring	0		0		0		0		122	15	107	107
	175		summer	0		0		564	247	317	322	128	194	250	115
			fall	0		0		388	61	327	0			0	388
Long Tangle Lake	200-	1	spring	0		0		0		6	0	6	318	82	236
	250		summer	0		0		19	16	3	193	115	78	120	62
			fall	0		0		0			0			0	0
Shallow Tangle Lake and Thoroughfare	251-	1	spring	0		0		0		242	23	219	171	52	119
	325		summer	0		71	69	2	71	60	11	0		142	134
			fall	0		0		0		23	5	18	0	23	5
Clear/18 Mile Creek	380-	2	spring	0		0		0		244	57	187	300	28	272
	392		summer	0		2	1	1	76	67	9	11	10	0	89
			fall	0		0		0		0		0		0	0
Landmark Gap Drainage	360-	3	spring	0		0		0		0		0		0	0
	375		summer	0		0		265	158	107	264	140	124	199	149
			fall	0		0		0		6	5	1	141	139	2
Round Tangle Lake and Thoroughfare	350,	1	spring	0		0		0		3	2	1	0	3	2
	400-		summer	0		21	7	14	138	85	53	34	21	13	0
	490		fall	26	24	2	10	7	3	0		0		36	31
Tangle River	500-	4	spring	0		0		0		0		0		0	0
	502		summer	0		159	154	5	29	24	5	4	2	2	0
			fall	181	175	6	309	294	15	239	227	12	115	101	14

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Appendix D2. (Page 2 of 2).

Locations				1986			1987			1988			1989			1990			Totals		
Site	Codes	Area	Season	All	Juv	Adult	All	Juv	Adult	All	Juv	Adult	All	Juv	Adult	All	Juv	Adult	All	Juv	Adult
Upper Tangle Lake	600-	6	spring	0			0			348	189	159	168	112	56	13	10	3	529	311	218
	605,		summer	0			17	14	3	67	17	50	0			0			84	31	53
	690		fall	11	9	2	0			14	1	13	103	11	92	0			128	21	107
Rock Creek	610-	5	spring	0			0			0			0			50	0	50	50	0	50
	680		summer	0			0			32	21	11	171	114	57	156	129	27	359	264	95
			fall	0			0			220	144	76	3	3	0	0			223	147	76
Glacier Lake	488	5	spring	0			0			0			0			0			0		
			summer	0			0			0			95	18	77	0			95	18	77
			fall	0			0			0			11	11	0	91	54	37	102	65	37
Upper Tangle River	700-	6	spring	0			0			0			93	81	12	19	16	3	112	97	15
	790		summer	0			0			0			4	4	0	0			4	4	0
			fall	0			0			205	198	7	0			0			205	198	7
Mud Lake to Headwaters	900-	6	spring	0			0			0			38	0	38	244	81	163	282	81	201
	905		summer	0			0			0			0			0			0		
			fall	0			0			0			0			0			0		
Sub totals:				0			0			348	189	159	794	275	519	1,237	284	953	2,379	748	1,631
				0			270	245	25	1,261	695	566	1,098	552	546	725	455	270	3,354	1,952	1,425
				218	208	10	319	301	18	1,066	631	435	261	136	125	232	193	39	2,096	1,469	627
Totals				218	208	10	589	546	43	2,675	1,515	1,169	2,153	963	1,190	2,194	932	1,262	7,829	4,169	3,683

^a Adult portion of catch determined by LM₅₀ of 289 mm FL. Juv = juvenile, 200 - 288 mm FL.

Appendix D3. Summary of all recaptures of Arctic grayling by maturity^a, season^b, and location tagged during spring in the Tangle Lakes system from 1988 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

		Numbers of recaptures by locations and season ^c																									
Tagging Location R/M ^f	Number Tagged ^d	Lower			18 Mile Cr			Landmark			Tangle R.			Rock Ck.			Upper			Unknown			Totals				
		sp ^e	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	ALL	
A; from test sampling:																											
Lower System	Total	862	31	18	4	0	0		1	0		0	0	0	0	0	0	0	0	0	0	0	31	19	4	54	0.06
	Adult	688	29	16	4				0														29	16	4	49	0.07
	Juv	174	2	2	0				1														2	3	0	5	0.03
18 Mile Creek	Total	544	5	5	0	23	1		4	0		0	0	0	0	0	0	0	0	0	0	28	10	0	38	0.07	
	Adult	459	5	4		19	1		0													24	5		29	0.06	
	Juv	85	0	1		4	0		4													4	5		9	0.11	
Landmark Gap Drainage	Total	0																									
	Adult																										
	Juv																										
Tangle River	Total	0																									
	Adult																										
	Juv																										
Rock Creek	Total	50	0	0	0	0	0		0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Adult	50																									
	Juv	0																									

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Appendix D3. (Page 2 of 4).

Numbers of recaptures by locations and season:

Tagging Location	Number Tagged	Lower			18 Mile Cr			Landmark			Tangle R.			Rock Ck.			Upper			Unknown			Totals				R/M
		sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	ALL	
A; from test sampling:																											
Mud Lake- Total	394	1	0		0			2	0		0		0	4	0	1	2	0	0	0	0	2	7	0	10	0.03	
Upper Adult	216	0						0						2		0	0					0	2		2	0.01	
Tangle R. Juv	178	1						2						2		1	2					2	5		8	0.04	
Upper Total	529	0	7	4	0	0		1	0		1	0	0	6	0	4	0	8	0	0	0	4	15	12	31	0.06	
Tangle Adult	218		5	2				0			0			1		2		4				2	6	6	14	0.06	
Lake Juv	361		2	2				1			1			5		2		4				2	9	6	17	0.05	
B; from anglers:																											
Lower Total	862	0	6	4	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	1	0	0	10	5	15	0.02	
System Adult	688		4	2					0	1		2							1				7	3	10	0.01	
Juv	174		2	2					1	0		0							0				3	2	5	0.03	
18 Mile Total	544	1	5	6	26	1	0	1	3	0	0	3	1	0	0	0	0	0	0	6	1	28	18	8	54	0.10	
Creek Adult	459	1	2	6	15	1		1	0			2	1						4	1		17	9	8	34	0.07	
Juv	85	0	3	0	11	0		0	3			1							2	0		11	9	0	20	0.24	
Landmark Total	0																										
Gap Adult																											
Drainage Juv																											

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Appendix D3. (Page 3 of 4).

		Numbers of recaptures by locations and season:																											
Tagging Location	Number Tagged	Lower			18 Mile Cr			Landmark			Tangle R.			Rock Ck.			Upper			Unknown			Totals				ALL	R/M	
		sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f				
B; from anglers:																													
Tangle River	Total	0																											
	Adult																												
	Juv																												
Rock Creek	Total	50	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0.02		
	Adult	50												1												1	1	0.02	
	Juv	0												0												0	0		
Mud Lake-Upper	Total	394	0	1	0	0	0	0	0	0	0	3	0	0	3	0	0	5	1	0	0	0	0	12	1	13	0.03		
	Adult	216	0														0	0			4		0	4			0	0.02	
Tangle R.	Juv	178	1														3	3			1		1	8			1	9	0.05

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Appendix D3. (Page 4 of 4).

		Numbers of recaptures by locations and season:																										
Tagging Location	Number Tagged	Lower			18 Mile Cr			Landmark			Tangle R.			Rock Ck.			Upper			Unknown			Totals				R/M	
		sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	ALL		
Upper	Total	529	1	5	2	0	0	0	0	1	0	3	7	4	0	4	0	3	0	2	3	1	2	10	18	10	38	0.07
Tangle	Adult	218	1	3	1					0		2	3	0		2		1		2	1	0	0	5	8	3	16	0.07
Lake	Juv	361	0	2	1					1		1	4	4		2		2		0	2	1	2	5	10	7	22	0.06

- a Maturity is based on maturity at time of tagging. Adult portion of catch determined by LM₅₀ of 289 mm FL.
- b Seasons: spring, 15 May through 15 June; summer, 16 June through 15 August; fall, 16 August through 15 October.
- c Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters
- d Number tagged: Total = all tags in location; Adult = all grayling greater than 288 mm FL are considered as mature (based on the length of maturity for 50% of the population); Juv = juveniles or those fish less than 289 mm FL.
- e sp = spring; s = summer; f = fall.
- f R/M = recapture rate, recaptures divided by number marked.

Appendix D4. Summary of all recaptures of Arctic grayling by maturity^a, season^b, and location tagged during summer in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

Tagging Location R/M ^f	Number Tagged ^d	Numbers of recaptures by locations and season:																								ALL	
		Lower ^c			18 Mile Cr			Landmark			Tangle R.			Rock Ck.			Upper			Unknown			Totals				
		sp ^e	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f		
A; from test sampling:																											
Lower System	Total	1,803	12	43	15	7	0			8	0			2	0	0	0	0	0	0	0	0	21	53	15	89	0.05
	Adult	896	7	27	11	5				1				0				1					13	28	11	52	0.06
	Juv	907	5	16	4	2				7				2				1					8	25	4	37	0.04
18 Mile Creek	Total	89	0	0	0	2	0			4	0			0	0	0	0	0	0	0	0	2	4	0	6	0.07	
	Adult	11				1				1												1	1		2	0.18	
	Juv	78				1				3												1	3		4	0.05	
Landmark Gap Drainage	Total	728	0	0	1	7	0			13	4			0	0	0	0	0	0	0	0	8	13	5	26	0.04	
	Adult	281			1	5				6	0							0				5	6	1	12	0.04	
	Juv	447			0	2				7	4							1				3	7	4	14	0.03	
Tangle River	Total	192	0	1	0	0	0			0	0			3	7	0	3	0	7	1	0	7	8	7	22	0.11	
	Adult	12		0										1	0		0		0	0		0	1	0	1	0.08	
	Juv	180		1										2	7		3		7	1		7	7	7	21	0.12	
Rock Creek	Total	454	0	0	0	1	0			0	0			0	10	14	1	0	0	0	0	2	10	14	26	0.06	
	Adult	172				1									7	10	1					2	7	10	19	0.11	
	Juv	282				0									3	4	0					0	3	4	7	0.02	
Upper System	Total	88	0	1	0	0	0			0	0			0	2	0	1	0	0	0	0	1	3	0	4	0.05	
	Adult	53		0											0		1					1	0		1	0.02	
	Juv	35		1											2		0					0	3		3	0.09	

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Appendix D4. (Page 2 of 3).

		Numbers of recaptures by locations and season:																											
Tagging Location	Number Tagged	Lower			18 Mile Cr			Landmark			Tangle R.			Rock Ck.			Upper			Unknown			Totals						
		sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	ALL	R/M		
B; from anglers:																													
Lower System	Total	1,803	0	16	4	2	0	0		0	0	0	4	1	3	0	0	0	0	1	1	0	1	0	6	19	8	33	0.05
	Adult	896		12	2	1							0	0	1				0	0		0		1	12	3	16	0.06	
	Juv	907		4	2	1							4	1	2				1	1		1		5	7	5	17	0.04	
18 Mile Creek	Total	89	0	1	0	2	0	0		0	0	0	0	1	1	0	0	0	0	1	2	0	0	0	0	5	3	8	0.09
	Adult	11		0		1								0	0				0	0					1	0	1	0.09	
	Juv	78		1		1								1	1				1	2					4	3	7	0.09	
Landmark Gap Drainage	Total	728	0	2	2	1	1	0		0	6	3	0	0	3	0	0	1	0	1	4	0	1	0	1	11	13	25	0.03
	Adult	281		0	0	0	1			4	2			1			0		0	2		1		0	6	5	11	0.04	
	Juv	447		2	2	1	0			2	1			2			1		1	2		0		1	5	8	14	0.03	
Tangle River	Total	192	0	4	1	0	0	0		0	0	0	2	8	1	0	1	0	0	0	0	0	0	2	13	2	17	0.09	
	Adult	12		1	0								0	0	0		0						0	1	0	1	0.08		
	Juv	180		3	1								2	8	1		1						2	12	2	16	0.09		
Rock Creek	Total	454	0	0	1	0	0	0		0	0	0	0	0	0	8	2	0	1	5	0	1	1	0	10	9	19	0.04	
	Adult	172			0											4	0		1	0		1	0	6	0	6	0.03		
	Juv	282			1											4	2		0	5		0	1	4	9	13	0.05		

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Appendix D4. (Page 3 of 3).

		Numbers of recaptures by locations and season:																									
Tagging Location	Number Tagged	Lower			18 Mile Cr			Landmark			Tangle R.			Rock Ck.			Upper			Unknown			Totals				R/M
		sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	ALL	
Upper System	Total	88	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	2	0.06
	Adult	53		0											0	0	1									0	
	Juv	35		1											1	1	0									2	0.06

^a Maturity is based on maturity at time of tagging. Adult portion of catch determined by LM₅₀ of 289 mm FL.

^b Seasons: spring, 15 May through 15 June; summer, 16 June through 15 August; fall, 16 August through 15 October.

^c Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters

^d Number tagged: Total = all tags in location; Adult = all grayling greater than 288 mm FL are considered as mature (based on the length of maturity for 50% of the population); Juv = juveniles or those fish less than 289 mm FL.

^e sp = spring; s = summer; f = fall.

^f R/M = recapture rate, recaptures divided by number marked.

Appendix D5. Summary of all recaptures of Arctic grayling by maturity^a, season^b, and location tagged during fall in the Tangle Lakes system from 1986 through 1990. Recaptures are partitioned to source: A, from test sampling; B, from voluntary angler returns.

		Numbers of recaptures by locations and season:																											
Tagging Location R/M ^f	Number Tagged ^d	Lower ^c			18 Mile Cr			Landmark			Tangle R.			Rock Ck.			Upper			Unknown			Totals						
		sp ^e	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	ALL			
A; from test sampling:																													
Lower System	Total	447	5	21	0	3	0			1	0			1	0	0	0	0	1	2	0	0	0	0	9	25	0	34	0.08
	Adult	350	5	14		3				1				1				1	1					9	17		26	0.07	
	Juv	97	0	7		0				0				0				0	1					0	8		8	0.08	
18 Mile Creek	Total	0																											
	Adult																												
	Juv																												
Landmark Gap Drainage	Total	147	0	0	0	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Adult	3																											
	Juv	144																											
Tangle River	Total	844	0	6	0	5	5			2	2			6	22	0	1	0	12	0	0	0	0	0	17	20	24	61	0.07
	Adult	47		1		1	0			0	0			0	0		0		1					2	1	0	3	0.06	
	Juv	797		5		4	5			2	2			6	22	1		11						15	19	24	58	0.07	
Rock Creek	Total	325	0	0	0	0	0			0	0			0	8	2		0	0	0		0	0	0	1	8	2	11	0.03
	Adult	113													1	1								0	1	1	2	0.02	
	Juv	212													7	1								1	7	1	9	0.04	
Upper System	Total	333	0	1	0	0	0			2	0			0	0	1		0	0	0		0	0	0	6	3	1	10	0.03
	Adult	114								0				0				3	1					3	1	0	4	0.04	
	Juv	219								2				1				3	0					3	2	1	6	0.03	

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Appendix D5. (Page 2 of 3).

		Numbers of recaptures by locations and season:																										
Tagging Location	Number Tagged	Lower			18 Mile Cr			Landmark			Tangle R.			Rock Ck.			Upper			Unknown			Totals					
		sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	ALL	R/M	
B; from anglers:																												
Lower System	Total	447	1	2	1	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	4	2	1	7	0.02
	Adult	350	1	1	0							1					0						2	1	0	3	0.01	
	Juv	97	0	1	1							1					1						2	1	1	4	0.04	
18 Mile Creek	Total	0																										
	Adult																											
	Juv																											
Landmark Gap Drainage	Total	147	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	3	3	0.02
	Adult	3			0									0						0						0	0	
	Juv	144			1									1						1						3	3	0.02
Tangle River	Total	844	0	4	0	0	0	0	0	1	0	5	17	7	0	0	0	1	2	0	0	5	0	6	29	7	42	0.05
	Adult	47		0						0		0	2	0				0	0			1		0	3	0	3	0.06
	Juv	797		4						1		5	15	7				1	2			4		6	26	7	39	0.05
Rock Creek	Total	325	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	1	1	1	0	0	0	1	3	2	6	0.02
	Adult	113			1											1		0	1	1			0	2	2	4	0.04	
	Juv	212			0											1		1	0	0			1	1	0	2	0.01	

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Appendix D5. (Page 3 of 3).

		Numbers of recaptures by locations and season:																										
Tagging Location	Number Tagged	Lower			18 Mile Cr			Landmark			Tangle R.			Rock Ck.			Upper			Unknown			Totals				R/M	
		sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	sp	s	f	ALL		
Upper System	Total	333	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	2	2	5	0	0	0	3	4	6	13	0.04
	Adult	114										1	1	0				1	2	4				2	3	4	9	0.08
	Juv	219										0	1	1				1	0	1				1	1	2	4	0.02

- ^a Maturity is based on maturity at time of tagging. Adult portion of catch determined by LM₅₀ of 289 mm FL.
- ^b Seasons: spring, 15 May through 15 June; summer, 16 June through 15 August; fall, 16 August through 15 October.
- ^c Lower system includes the Upper Delta River through Round Tangle Lake; 18 Mile Creek includes the Clear Creek drainage; Landmark is the Landmark Gap Lake drainage; Tangle River is the interconnecting stream between Upper and Round Tangle lakes; Rock Creek is the entire drainage including Glacier Lake; Upper system includes Upper Tangle Lake and Upper Tangle River through Mud Lake to the Tangle System headwaters
- ^d Number tagged: Total = all tags in location; Adult = all grayling greater than 288 mm FL are considered as mature (based on the length of maturity for 50% of the population); Juv = juveniles or those fish less than 289 mm FL.
- ^e sp = spring; s = summer; f = fall.
- ^f R/M = recapture rate, recaptures divided by number marked.